AD-A123 896 OCEANIC AREA SYSTEM IMPROVEMENT STUDY (OASIS) VOLUME I 1/5
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CA G J COULURIS ET AL. SEP 81 OASIS FAA-EM-81-17-1
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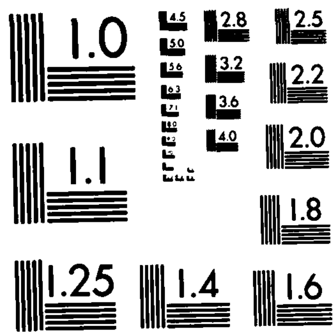
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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-EM-81-17, I	AD-A123896	

4. Title and Subtitle	5. Report Date
OCEANIC AREA SYSTEM IMPROVEMENT STUDY (OASIS) VOLUME I: EXECUTIVE SUMMARY AND IMPROVEMENT ALTERNATIVES DEVELOPMENT AND ANALYSIS	September 1981
	6. Performing Organization Code: SRI Project 8066
7. Author(s): G.J. Couluris, B. Conrad	8. Performing Organization Report No.: OASIS
9. Performing Organization Name and Address: SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.: DOT-FA79WA-4265
12. Sponsoring Agency Name and Address: Department of Transportation, Federal Aviation Administration, Office of Systems Engineering Management, Washington, D.C. 20591	13. Type of Report and Period Covered: Final Report
	14. Sponsoring Agency Code: FAA-AEM

15. Supplementary Notes

This document is also Volume III of the Report of the International "Committee to Review the Application of Satellite and Other Techniques to Civil Aviation."

16. Abstract

The Oceanic (and selected Non-Oceanic) Area System Improvement Study (OASIS), conducted by SRI International under contract with the Federal Aviation Administration (FAA), was part of a broad oceanic aeronautical system improvement study program coordinated by the "Committee to Review the Application of Satellite and Other Techniques to Civil Aviation" (also called the Aviation Review Committee or the ARC). The OASIS Project, with inputs from the international aviation community, examined current and potential future oceanic air traffic control (ATC) systems in the North Atlantic (NAT), Central East Pacific (CEP), and Caribbean (CAR) regions. This phase of the Aviation Review Committee program began in late-1978 and was completed in mid-1981.

The thrust of the Aviation Review Committee program, which OASIS broadly supported, was to analyze the present ATC systems; examine future system requirements; identify areas where the present systems might be improved; and develop and analyze potential system improvement options. The time frame of this study is the period 1979 to 2005.

This report describes potential improvement alternatives to air traffic services (ATS) systems in the NAT, CEP, and CAR. The improvements would affect the communication, navigation, and surveillance functions, and include: vertical separation minimum reduction above Flight Level 290; an airborne separation assurance device; automatic dependent surveillance with either network HF data link and voice or satellite data link and voice; cooperative independent surveillance with multiple satellite data link and voice; and combinations and derivatives of these improvements including a simple network HF data link and voice system. The provider and user costs of the potential impovements were estimated, including capital, operating and maintenance, and flight costs. The flight costs for fuel, crew, and maintenance were estimated using the Flight Cost Model (FCM) computer program which simulates alternative separation minima and operations corresponding to selected potential improvement configurations, and considers anticipated future traffic. The total costs to the year 2005 of the improvement configurations were compared to assess their economic feasibilities.

17. Key Words	18. Distribution Statement
Air Traffic Services (ATS), Oceanic Air Traffic Control (ATC), Communication (COM), Navigation (NAV), Surveillance	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	412	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Oceanic Area System Improvement Study (OASIS)

Final Report

This report is one of a set of companion documents which includes the following volumes:

Volume I
Executive Summary and Improvement Alternatives Development and Analysis

Volume II
North Atlantic Region Air Traffic Services System Description

Volume III
Central East Pacific Region Air Traffic Services System Description

Volume IV
Caribbean Region Air Traffic Services System Description

Volume V
North Atlantic, Central East Pacific, and Caribbean Regions Communication Systems Description

Volume VI
North Atlantic, Central East Pacific, and Caribbean Regions Navigation Systems Description

Volume VII
North Atlantic Region Flight Cost Model Results

Volume VIII
Central East Pacific Region Flight Cost Model Results

Volume IX
Flight Cost Model Description

Volume X
North Atlantic, Central East Pacific, and Caribbean Regions Aviation Traffic Forecasts

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

PREFACE

The Oceanic Area System Improvement Study (OASIS) was conducted in coordination with the "Committee to Review the Application of Satellite and Other Techniques to Civil Aviation (also called the Aviation Review Committee or the ARC)." This study examined the operational, technological, and economic aspects of the current and proposed future oceanic air traffic systems in the North Atlantic (NAT), Caribbean (CAR), and Central East Pacific (CEP) regions and assessed the relative merits of alternative improvement options. A key requirement of this study was to develop a detailed description of the present air traffic system. In support of this requirement, and in cooperation with working groups of the Committee, questionnaires were distributed to the providers and users of the oceanic air traffic systems. Responses to these questionnaires, special reports prepared by system provider organizations, other publications, and field observations made by the OASIS staff were the basis for the systems descriptions presented in this report. The descriptions also were based on information obtained during Working Group A and B meetings and workshops sponsored by Working Group A. The information given in this report documents the state of the oceanic air traffic system in mid 1979.

In the course of the work valuable contributions, advice, data, and opinions were received from a number of sources both in the United States and outside it. Valuable information and guidance were received and utilized from the International Civil Aviaiton Organization (ICAO), the North Atlantic Systems Planning Group (NAT/SPG), the North Atlantic Traffic Forecast Group (NAT/TFG), several administrations, the International Air Transport Association (IATA), the airlines, the International Federation of Airline Pilots Association (IFALPA), other aviation associated organizations, and especially from the "Committee to Review the Application of Satellite and Other Techniques to Civil Aviation."

It is understood of course, and should be noted, that participation in this work or contribution to it does not imply either endorsement or agreement to the findings by any contributors or policy agreement by any administration which graciously chose to contribute.

ACKNOWLEDGEMENT

A study effort the size of OASIS could not have been undertaken and completed without the participation and commitment of numerous individuals. In fact, as indicated by the extensive organizational membership of the "Committee to Review the Application of Satellite and Other Techniques to Civil Aviation" (also called the Aviation Review Committee or the ARC) as described in the Preface, the large number of people participating in the study precludes the acknowledgement of the contributions of each individual. However, we do wish to identify those persons most active on a daily basis in this project, and we specifically refer to the FAA personnel involved in the guidance and review of the study from its inception. These include: Mr. S. B. Poritzky, Director of the Office of Systems Engineering Management; Mr. Victor E. Foose, the OASIS Program Manager; Mr. Nicholas M. Craddock; and Mr. James Loos. We also wish to acknowledge the important functions performed by Mr. Roy Cox, Chairman of the Aviation Review Committee, and the Committee's secretariat.

This work was performed by SRI International under the leadership of Dr. George J. Couluris and the administrative supervision of Dr. Robert S. Ratner and Mr. Joel Norman. SRI personnel who directed major OASIS project tasks include Dr. Bjorn Conrad, Dr. Claire Starry and Dr. John Bobick. Key project members whose efforts were critical to the development of the Flight Cost Model include Dr. Kai Yuen Wang and Dr. Donato D'Esopo. Ms. Janet Tornow and Mr. David Koretz were instrumental in developing this report. Other important SRI team members include Dr. John Ames, Ms. Mina Chan, Mr. Andre Dermant, Ms. Marika Garskis, Ms. Linda Gill, Mr. Bert Laurance, Mr. Robert Lieberman, and Mr. Paul Wong. Grateful recognition is given to Ms. Geri Childs who prepared this report.

TABLE OF CONTENTS (CONTINUED)

S.0 EXECUTIVE SUMMARY

S.1 Introduction

This study assesses the technical, operational, and economic feasibilities of developing and applying potential improvements to air traffic services (ATS) in selected oceanic and low air traffic density areas, while maintaining or enhancing the level of safety. The improvements of primary concern are those that can enhance separation assurance services and reduce overall operating costs. Flight operating costs may be decreased by reducing constraints imposed by current separation minima. The improvements address communication, navigation, surveillance, and self-contained airborne separation assurance functions and associated operating procedures.

The work accomplished has provided quantitative data that can be used by the world aviation community to narrow significantly the choices for improving ATS systems in oceanic areas of the world and in other areas where similar systems can enhance air traffic services. The data is based both on economic assumptions and forecasts, and on analyses or judgements of the feasibility of achieving certain of the technical improvements sought. Within the set of choices, these parameters must be refined, and detailed implementation plans developed and examined before singular decisions can be made. And of course, future ATS improvement decisions must continue to be made in the successful evolutionary context of past and ongoing improvement and enhancement plans.

The study evaluated potential improvements by developing design concepts for each improvement (based on technical and operating requirements) and then estimating and comparing the costs of developing and implementing the improvements and the flight operating costs associated with each improvement. The study yielded the following results.

(1) The application of 1000 feet (ft) vertical separation minimum above flight level (FL) 290 in oceanic and domestic areas, and only in oceanic areas as a possible alternative, would achieve large savings in system operating costs due to reductions in user flight costs (i.e., total fuel, crew and maintenance costs). The user flight cost savings are sufficiently large to justify significant cost in research and development, avionics upgrading or implementation of technology to support the 1000 foot vertical minimum.

(2) The application of 30 nmi lateral and 5 min longitudinal minima, or of 15 nmi lateral and 2 min longitudinal minima based on the implementation of any of the potential improvements listed below in conjunction with the indicated navigation system performance improvements will yield overall cost efficiencies (the navigation system improvements are identified later in this executive summary and are assumed to be developed in an evolutionary manner).

- Use of airborne separation assurance devices to enable aircraft to detect potential conflicts and avoid them, (which might achieve 30 nmi lateral and 5 min longitudinal and 2000 ft vertical--30 nmi/5 min/2000 ft--minima in conjunction with an improved Minimum Navigation Performance Secification (MNPS (Improved)).

- Automatic dependent surveillance using a new high frequency (HF) data link and voice communication system that provides direct pilot to controller communications, which might achieve 30 nmi/5 min/2000 ft minima in conjunction with MNPS (Improved).

- Automatic dependent surveillance using a satellite data link and voice communication system which provides direct pilot to controller communications, which might achieve 30 nmi/5 min/2000 ft minima in conjunction with MNPS (Improved).

- Combinations of the dependent surveillance systems and use of airborne separations assurance devices, which might further support the 30 nmi/5 min/2000 ft minima in conjunction with MNPS (Improved).

- Cooperative independent surveillance of aircraft using a multiple satellite data link and voice communications systems, which might achieve 15 nmi/2 min/2000 ft minima in conjunction with an MNPS (Advanced).

(3) A simple network HF data link and voice communications improvement capable of providing direct pilot-to-controller communications has been estimated to provide potential cost savings without reduced separation minima. The cost savings would result from partially automating some manual processes involved in operating the current high frequency (HF) single sideband (SSB) voice communication system.

The above improvements include airborne separation assurance device and surveillance functions. However, the applicaion of these functions are never assumed to be a substitute for adequate navigation system performance, but are intended primarily to prevent potential conflicts due to large navigation errors.

The potential cost benefits of the vertical improvements in the North Atlantic (NAT) oceanic region could be on the order of 450 million discounted dollars considering operations through the year 2005, assuming no improvements in altimetry are needed. Lateral and longitudinal separation reductions have indicated comparable benefits on the order of 150 million discounted dollars. The corresponding benefits estimated for the Central East Pacific (CEP) oceanic region are on the order of 100 million and 50 million discounted dollars for the vertical and the lateral and longitudinal minima reductions, respectively.

Some of the improvements offer less sensitivity to assumptions concerning implementation costs and technical feasibility. For example, both 1000 ft vertical separation above FL 290 and the use of a separation assurance device yield significant flight cost reductions based on moderate capital investments, and the estimated cost efficiencies associated with these improvements would not be jeopardized by reasonable changes to the cost estimation assumptions. As another example, the network HF data link and voice system requires additional developmental study to confirm its technical ability to overcome HF propogation limitations and provide the communications reliability necessary to support a reduction of separation minima, when used in conjunction with automatic dependent surveillance. The comparable automatic dependent surveillance with a satellite data link and voice system has less technical uncertainty.

Some of these improvements could provide benefits which are not quantified in terms of cost. For example, the use of the separation assurance device has the potential for enhancing safety in airspace areas in which limited air traffic services are provided, and the application of automatic dependent surveillance to impact the level of tactical control could provide additional unquantified user cost savings even without a reduction in separation minima.

Important variations of the above improvements have also been considered. For example, deleting the voice requirement from a satellite system could save the aviation community about 35 million discounted dollars over the cost of a comparable system which includes a voice channel. Also, the use of a simple network HF data link and voice system with separation minima reduction could yield significant cost efficiencies based on reduced user flight costs.

The remainder of this summary contains a more detailed review of the improvements considered and the results of the analyses conducted for the NAT, CEP and Caribbean (CAR) regions.

S.2 Potential Improvements

S.2.1 Background

The types of ATS systems presently implemented and operating procedures currently used in various parts of the world have regional variations consistent with geographic constraint. In oceanic areas, the lack of suitable land sites preclude the installation of line-of-site communications and the HF air-ground voice communication is used. Long-range navigation techniques include doppler system, inertial navigation systems (INS) and Omega. Pilot-to-controller communications are conducted with a radio operator intermediary. Aircraft position reports relayed to traffic controllers are used for flight monitoring purposes.

While these current systems have proved adequate to support safe flight operations, the question arises as to the potential for reducing flight costs by reducing lateral, longitudinal and vertical separation minima. These minima are established by international agreement based in part on the operating characteristics of the communication, navigation and surveillance systems, and reflect the capability of the ATS system to monitor aircraft flight progress (e.g., present position and future position estimates), and intervene and resolve potential violations of the separation minima (i.e., potential conflicts). In particular, the magnitude of the separation minima are influenced by the ability of ATS system to recognize potential conflicts (including those due to deviations from assigned flight paths in controlled airspace), determine corrective actions, and communicate appropriate clearances to aircraft in a timely manner.

Current systems in oceanic and various low traffic density areas support comparatively large lateral and longitudinal separation minima, relative to domestic systems using radar. For example, the separation minima planned for application by 1982 in the NAT oceanic region are 60 nmi laterally, 10 min longitudinally (under constant Mach number technique procedures) and 2000 ft vertically (60 nmi/10 min/2000 ft). Those minima are established in conjunction with MNPS, which requires the system to satisfy stipulated navigation performance specifications. In the CEP, the corresponding separation minima are 100-50 nmi/15 min/2000 ft, where 100-50 nmi indicates a composite system. Similar separation minima are applied in areas such as the CAR and Africa (AFI) regions, but with allowances for local reductions according to the availability of ground based facilities.

Also, strategic control procedures are commonly used. The strategic control procedures require assignment of conflict free flight paths to aircraft for long flight distances (e.g., for the length of an over-ocean flight segment). Tactical control procedures, in which potential conflict intervention is conducted on a minute-by-minute basis, are rarely used in these areas. The relatively large separation minima and associated strategic procedures introduce extended diversions from preferred flight paths when potential conflicts are resolved. The user

flight costs of such diversions can be reduced by separation minima reductions (and by the introduction of capabilities for controllers to effect more tactical control).

The Committee to Review the Application of Satellite and Other Techniques to Civil Aviation (the Aviation Review Committee or the ARC) has considered and identified various potential improvements as means to enhance separation assurance service and to enable reductions of separation minima. An analysis of the ATS user and provider capital and operating costs has been conducted based on the potential improvements identified by the Aviation Review Committee. The descriptions of the major improvements and their costs, as presented in the following paragraphs relative to NAT implementations, are based in large part on the considerations made by the Aviation Review Committee. The applications of potential improvements in the CEP and CAR are addressed later in this executive summary.

S.3 NAT Potential Improvement Implementations

S.3.1 Vertical Improvements

The operation of aircraft with a 1000 ft vertical separation minimum above FL 290 is the most important improvement option in terms of potential savings in fuel and other operating costs. The United States Federal Aviation Administration (FAA) is considering a plan to determine the potential for reduction of vertical separation above FL 290 to 1000 ft. In this study, estimated costs of that plan were combined with assumed costs for possible avionics improvements to permit calculation of the sensitivity of vertical minimum reduction cost benefits to costs of system changes which a research and development program based on test outcomes might yield. A vertical performance specification (PS) is expected to be required in conjunction with 1000 ft vertical separation above FL 290.

S.3.2 Airborne Separation Assurance Device

These self-contained airborne devices would detect otherwise undetected conflicts and would identify collision avoidance maneuvers. Such devices, in conjunction with MNPS (Improved), might provide a margin of safety, with respect to occasional navigation errors, adequate to allow reductions of minimums to 30 nmi laterally and 5 min longitudinally while holding fixed the 2000 ft vertical minimum. The MNPS (Improved) establishes new navigation system performance specifications which are more stringent than the present MNPS and which should help limit the frequency of navigation deviations to the degree that the occurrences of collision avoidance maneuver are limited to an acceptable level.

Available information on prototypes being developed and tested by the FAA was used to estimate costs and make calculations demonstrating the characteristics of such devices. The separation asurance device was considered under the assumptions that either 100% or 50% of the user avionics capital costs are allocated to NAT operations.

S.3.3 Automatic Dependent Surveillance with Network HF Data Link and Voice

This improvement would enable air traffic control (ATC) units to monitor aircraft movement using aircraft position data derived by aircraft avionics systems and automatically transmitted to the ground units by HF data link. Pilots and controllers would conduct direct digital data and occasional voice communications between each other using the HF radio frequencies. Automated ATC data handling, traffic situation displays for controllers, and associated advanced ATC automation are included in this improvement, and would be employed to support air traffic control operations.

Otherwise unresolved interruptions to HF air-ground communication due to ionospheric propagation vagaries would be circumvented through spacial and frequency diversity techniques. Spacial diversity would be obtained using five HF ground communication stations in a systematic manner. The stations would all be connected to and controlled by each or either of two master control stations (each on different sides of the Atlantic) to form a network. The master stations coordinate and control polling of aircraft by dynamically assigning frequencies and aircraft to particular ground stations. Frequency diversity would be achieved with sounding techniques. In particular, ground stations would transmit periodically on all the frequencies being used, and the aircraft avionics would be capable of continuously identifying and choosing satisfactory frequencies suitable for communications during each portion of that aircraft's flight. Existing HF SSB avionics would be enhanced to support this improvement. The existing HF single side band (SSB) ground station equipment would be supplemented considerably, and some sites might be moved or otherwise reconfigured.

The HF network would be designed to service a peak instantaneous aircraft count exceeding 200 aircraft (i.e., estimated traffic for the year 2005). Most aircraft would be polled to obtain position data every five minutes, and aircraft pairs operating close to the separation minima would be polled as frequently as deemed necessary, possibly once every 30 seconds.

The existing HF (SSB) ground station radio operator staffs would be reduced relative to their projected size. These operators, who would handle residual HF SSB voice communications, would operate within facilities scaled to the projected size of existing HF SSB communication stations such as the one in San Juan. The automated communication system facilities would be colocated and integrated with the existing stations.

This improvement, in conjunction with MNPS (Improved), is assumed to support a reduction in separation minima to 30 nmi laterally and 5 min longitudinally while maintaining the 2000 ft vertical minimum, subject to the conditions that: (1) the distribution of along-track and cross-track navigation errors would be compatible with an acceptable level of safety for these reduced minima; note that the MNPS (Improved) should ensure that the main bodies of the lateral navigation performance distribution would not significantly overlap with the 30 nmi lateral minimum; and (2) in regard to the tails of the distribution, the automatic dependent surveillance function would be capable of sufficient detection of large errors such that corrective action could be taken by controllers to preclude those deviations from developing to the point of posing a collision risk, and that the frequency of such detection and corrective actions would be limited to an acceptable level of occurrence; note that direct pilot-controller communication should allow real time monitoring and intervention as necessary to assist in achieving and maintaining the 5 min longitudinal minimum. This improvement in conjunction with an airborne separation assurance device and MNPS (Improved) would protect against potential collision risk associated with undetected large errors, and would also support establishment of the 30 nmi lateral and 5 min longitudinal separation minima.

These reduced separation minima are assumed to be applied in 1990, which would allow time for system development and implementation. However, even with this sophisticated HF system design, a significant test program is anticipated to be needed to determine if sufficient communication link reliability would be available to support the minima reductions.

S.3.4 Simple Network HF Data Link and Voice With and Without Separation Minima Reduction

A simple network HF data link concept was examined as a lower cost means for providing direct pilot-to-controller digital data communications, with occasional voice services being provided by appropriate residual HF SSB capabilities. This concept essentially involves the establishment of HF data link capabilities at the existing ground facilities and on aircraft, and the provision of upgraded data links between the ground facilities. This network would be controlled by two master control stations (one on each side of the Atlantic), but would not employ systematic sounding and frequency agility to the extent of the automatic dependent surveillance with network HF data link and voice system which is described in the preceding paragraphs. Aircraft would be polled to obtain position data on the average of once every five minutes.

Three options were considered: one that is assumed not to support any reduction of separation minima; one that is assumed to support a reduction to 30 nmi/5 min/2000 ft in conjunction with MNPS (Improved); and one that consists of the previous option plus the airborne separation assurance device. The three options are assumed to accomplish the

following improvements: (1) provide direct pilot-to-controller communications, (2) increase communication reliability (due to signal structure, coding, and automatic retransmission possibilities, (3) provide a basis for implementing automatic dependent surveillance, (4) effect better airspace utilization and increased tactical control (through improvements (1) through (3) above), and (5) reduce the level of labor intensiveness associated with the present voice based system. The options are assumed to have the same level of ATC automation and display hardware implementation as the network HF data link and voice improvement. The only difference assumed between the first and the other two alternatives, from the system design and operational aspects, is that the first would have a single unit avionics installation, while the other two would have a dual unit installation to support the separation minima reduction.

In regard to the simple network HF data link and voice without separation minima reduction, single-unit HF avionics equipment is assumed to be installed gradually beginning in the mid-1980s, with full fleet equippage occuring by 1993. This schedule would allow expansion to dual-unit HF avionics in the early 1990s if a decision is made to evolve to simple network HF data link and voice with separation minima reductions in conjunction with MNPS (Improved); such a decision is contingent on the determination that the simple network HF data link and voice system is capable of supporting 30 nmi lateral and 5 min longitudinal minima subject to the conditions as stated previously for the case of automatic dependent surveillance with network HF data link and voice. The addition of the airborne separation assurance device would protect against potential collision risk associated with undetected large errors, and would provide protection against collision if the data link system link reliability became poor for a period of time.

S 3.5 Automatic Dependent Surveillance with Satellite Data Link and Voice

This improvement, like the network HF and simple network HF data link and voice improvements, would enable air traffic control units to monitor aircraft movement by using aircraft position data derived from aircraft avionics systems and automatically transmitted to the ground units by a satellite data link. Pilots and controllers would conduct direct digital data and occasional voice communications with each other using the satellite relay. Automated ATC data handling, controller displays, and advanced ATC automation would be employed to support air traffic control operations.

The air-ground (via ground-satellite and satellite-aircraft links) communications would be provided by satellite transponders. The transponders are assumed to be part of a small aviation package on a geostationary satellite along with other non-aviation payloads. One

operational and one spare transponder are assumed, each on a separate satellite in orbit. The system would have one voice channel per transponder. Aircraft would be polled on C-band ground-satellite links and L-band satellite-aircraft links to obtain position data. Two master earth stations (one on each side of the Atlantic) would control the polling of aircraft and the distribution of poll data to ATC facilities. Air traffic control units would be linked to the master earth stations by C-band ground-ground links provided as part of the aviation satellite package capability. Aircraft would carry dual L-band transceivers and one L-band antenna in addition to HF SSB equipment currently in use.

Existing HF SSB ground stations would continue to function with much smaller staffs and less equipment than would be required if no improvements in the communications system were made. The existing facilities and staffs would be scaled to the projected size of small existing stations such as the one in San Juan.

The satellite transponders and supporting ground stations would be designed to service a peak instantaneous aircraft count of more than 200 aircraft (i.e., the estimated year 2005 requirement). Most aircraft would be polled at 5 minute intervals, and aircraft pairs operating close to the separation minima would be polled as frequently as once every 30 seconds.

This improvement, in conjunction with MNPS (Improved), is expected to support the application of 30 nmi and 5 min longitudinal separation minima in 1990, which would allow time for system development and implementation. Implementation of the reduced separation minima is subject to the same conditions specified in preceding paragraphs for automatic dependent surveillance with network HF data link and voice regarding navigation deviations and their detection and correction. However, communication link reliability is not an unknown element as in the case of HF systems. This satellite-based improvement, in conjunction with an airborne separation assurance device and MNPS (Improved), would further protect against potential collision risk and would also support establishment of the 30 nmi lateral and 5 min longitudinal separation minima in 1990.

S.3.6 Cooperative Independent Surveillance with Multiple Satellite Data Link and Voice

This improvement would enable air traffic control units to monitor aircraft movements by using aircraft position data calculated by the ground units based on signals received from aircraft carrying compatible transponders (i.e., transponders analogous to those used with secondary surveillance radar), which are integral parts of the avionics units. Pilots and controllers would conduct direct digital data and occasional

voice communications with each other using the multiple satellite communication relay capability. Automated ATC data handling, controller displays and associated advanced ATC automation would be employed to support air traffic control operations.

Surveillance would be accomplished by satellite communication links connecting the master control earth stations and aircraft. The air-ground and ground-ground communications for this improvement would be as described above for the automatic dependent surveillance with satellite data link and voice alternative. Two operational satellite transponders, each on a different geostationary satellite would be required to provide the capability for determining aircraft position (i.e., to satisfy the cooperative independent surveillance function), and one additional satellite transponder is assumed to be in orbit on a third satellite as a spare. It is assumed in the cost analysis in this study that the transponder packages would share the satellite platforms with other users; however, because of satellite location constraints associated with the cooperative independent surveillance function, this might not be possible (if dedicated satellites are required, the costs would be significantly higher). Dual L-band avionics installations are assumed. The satellite data links would be designed to service a peak instantaneous aircraft count of more than 200 aircraft (i.e., estimated requirements for the year 2005). Most aircraft would be polled at 5 minute intervals, and aircraft pairs operating near separation minima would be polled once every 30 seconds.

This improvement, in conjunction with MNPS (Advanced) is assumed to support the application of 15 nmi lateral and 2 min longitudinal separation in 1995, which would allow time for system development and implementation; the MNPS (Advanced) is more stringent than the MNPS (Improved). In this case, the application of the reduced minima are subject to conditions analogous to those stipulated previous for the automatic depenaent surveillance with data link and voice except that the 15 min lateral and 2 minute longitudinal minima apply with MNPS (Advanced) instead of 30 nmi and 5 min with MNPS (Improved). Note that cooperative dependent surveillance provides a capability to detect all navigation system errors independent of the navigation system.

S.3.7 60-30 Composite

In addition, several possible means of achieving 60-30 nmi composite separation were considered subject to various uncertainties in the system requirements necessary to support the composite separation. Achievement of a 60-30 nmi composite lateral separation in conjunction with 10 min longitudinal and 2000 ft vertical minima in 1985 might be considered to be based on an extension of present operations, and might involve improvements in lateral or vertical navigation performance or both.

S.4 NAT Configurations and Cost Comparisons

S.4.1 Cost Comparison Methodology

Various potential improvement configurations were identified that represented assumed ATS system operating alternatives during the 1979 through 2005 study period; these configurations are listed in Table S-1. A baseline configuration represented continuation of the present ATS system and associated separation minima, considering planned improvements. The improvement configurations were assumed to represent a time-phased evolutionary improvement program that included separation minima reduction transitions. Each potential improvement configuration represented continuation of baseline operations until the year of implementation of an improvement operation, at which time the appropriate separation minima reductions were assumed to apply.

The user and provider capital and operating costs for each configuration were estimated for the 1979 through 2005 study period. The capital and operating costs for the potential improvements were based largely on engineering analysis of the component costs of the proposed designs. These costs included the expenses required for developing, purchasing, and installing the requisite improvement equipment and the associated annual operating and maintenance costs. An 8% annually compounded cost inflation rate was assumed.

The user flight operating costs for fuel, crew and maintenance were estimated by the Flight Cost Model, a computer simulation especially developed for this study. The FCM, which was validated by the Aviation Review Committee for the purposes of comparing the relative costs of ATS operating alternatives, replicates traffic loading, route structures, meteoroligical conditions, fuel burn and flight performance characteristics by aircraft type, airline flight planning procedures, separation minima, and the control procedures and conflict diversion and delay strategies used by air traffic control authorities. The FCM was used to simulate flight operations with step climb procedures and costs corresponding to various separation minima over a range of traffic projections, and thereby provided a means to estimate the annual flight costs associated with each potential improvement, except Configuration 20, based on the traffic forecasted for each year (the forecasts were developed in coordination with the Aviation Review Committee). User fuel costs were inflated at a 10% annually compounded inflation rate. User flight cost savings corresponding to free flight in the vertical plane operations of Configuration 20 were estimated by the United Kingdom (UK) at the request of the Aviation Review Committee.

The 1979 present value of the estimated user and provider expenditures during the 1979 through 2005 study period were calculated for each configuration based on a 12% discount rate for user costs and a 10% discount rate for provider costs. The present value total costs for

Table S-1

NAT 1979–2005 PRESENT VALUE COST INCREMENTS BY CONFIGURATION RELATIVE TO BASELINE
(1979 Discounted US $ Millions)

Configuration†	User Net Cost		Provider Net Cost		User and Provider Net Cost*		
	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Total Cost Saving
1. Baseline, HF SSB Voice, MNPS, 120–60 nmi/15 min/2000 ft through 1980, 60 nmi/15 min/2000 ft in 1981, 60 nmi/10 min/2000 ft in 1982 through 2005	0	0	0	0	0	0	0
2. 60–30 Composite, HF SSB Voice, MNPS, 60–30 nmi/10 min/2000 ft in 1985 through 2005	0	78	0	0	0	78	78
3. 60–30 Composite, HF SSB Voice, MNPS (Improved) and/or improved vertical performance, 60–30 nmi/10 min/2000 ft in 1985 through 2005	0	78	0	0	0	78	78
4. 1000 ft Vertical Separation Above FL 290 Oceanic Only, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005	0	453	6	0	6	453	448
5. 1000 ft Vertical Separation Above FL 290 Oceanic Only With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005	11	403	6	0	17	403	387
6. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005	0	615	6	0	6	615	609
7. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005	11	545	6	0	17	545	528
8. Airborne Separation Assurance Device With 100% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005 §	64	167	1	0	65	167	102
9. Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005 §	32	167	1	0	33	167	134
10. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	54	167	40	78	94	244	150
11. Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	86	150	41	78	127	228	101

Table S-1 (Concluded)

12. Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1987 through 2005	24	-16	33	92	57	75	15**
13. Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (improved), 30 nmi/5 min/2000 ft in 1993 through 2005	43	138	33	92	76	230	154
14. Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005	78	124	34	92	112	216	104
15. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	64	167	65	107	129	274	145††
16. Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	96	150	66	107	162	257	96††
17. Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	44	167	51	107	95	274	179††
18. Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	76	150	52	107	128	257	130††
19. Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005 ††	51	222	58	75	109	296	187§§
20. Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane, 15 nmi/2 min/2000 ft in 1995 through 2005 ††	51	288	58	75	109	363	253§§
21. Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 1994 and 15 nmi/2 min/2000 ft in 1995 through 2005 ††	51	248	58	75	109	323	214§§

*Discrepancies in addition are due to roundoff.

†The baseline system and separation minima are assumed in operation for each configuration until the further reductions indicated for the other configurations are achieved.

§These configurations may under some conditions require more frequent position reporting (i.e., at intervals of 5° longitude rather than the current 10° longitude) to allow early controller detection and intervention in cases of erosions of the longitudinal separtion minimum. The more frequent position reporting will lead to increased pilot, controller and radio operator workload. The net impact of which has not been fully assessed.

**The indicated net cost saving does not include any flight cost reductions due to better utilization of airspace and associated tactical control.

††The indicated net cost savings may be reduced by $47 million for Configurations 15 and 16 and by $61 million for Configurations 17 and 18 to account for increased provider capital costs caused by a non-optimum space segment sharing arrangement.

§§The indicated net cost savings may be reduced by $50 million because of the additional user capital costs likely to be required for MNPS (Advanced). Dedicated satellite implementation, rather than the assumed optimum sharing, would also reduce the indicated net cost savings by a further $122 million because of increased provider capital costs.

each improvement configuration were subtracted from those of the baseline configuration to determine the net cost savings associated with each improvement over the study period. The resulting net total cost savings relative to the baseline configuration are shown in the right hand column in Table S-1. Table S-1 also shows the user and provider capital cost increases and operating cost decreases (each relative to the baseline costs) for each configuration. The improvement implementations and associated separation minima reduction transition schedules are identified in Table S-1 for each configuration.

S.4.2 1000 ft Vertical Separation Above FL290

The implementation in 1988 of 1000 ft vertical separation with improved altimetry and MNPS (Vertical) in only oceanic airspace would, as shown in Table S-1, obtain a net savings of $387 million, and a net savings of $528 million if implemented in oceanic and domestic airspace. The capital and operating costs associated with aircraft altimetry improvements are provided for cost sensitivity purposes only and are not related to any specific improvements. If the user capital costs for the avionics ($11 million in Table S-1) were underestimated by a factor of two, the capital cost estimate should be doubled. This calculation will reduce net total cost savings slightly, but the savings will remain very large, indicating that the 1000 ft vertical separation minimum is meaningfully attractive in economic terms. The same conclusion would be drawn if the net savings sensitivities to variations in user operating costs were similarly examined.

S.4.3 Airborne Separation Assurance Device

The implementation of the airborne separation assurance device with 100% avionics capital cost allocation to NAT operations, MNPS (Improved), and 30 nmi/5 min/2000 ft separation minima in 1990 also shows a significant net savings of $102 million. In this case, the user capital cost net increase ($64 million) and provider capital cost net increase ($1 million) is more than offset by the large net decrease in user operating costs ($167 million). Even if the user capital costs were underestimated by 50% (i.e., capital cost net increases are actually half again greater than those indicated), significant net savings ($70 million) still would be obtained, which indicates that this configuration is economically attractive. The separation assurance device with 50% avionics capital cost allocation to NAT operations would further increase the economic gains because of the lower capital costs relative to the 100% allocation.

Table 4-1 (in the main text of this report) as initially established in the 4th Meeting (Williamsburg) of the Aviation Review Committee specified direct pilot-to-controller communications as a requirement for reducing the longitudinal separation minimum to 5 min. Subsequently, at the 5th Meeting (Malaga), the airborne separation assurance device improvements (Configurations 8 and 9) were associated with the 5

min longitudinal separation, but required only HF SSB voice, apparently in oversight of Table 4-1. The contradiction surfaced at the 6th Meeting (Ottawa), and the Committee discussions revealed differences of opinion on whether HF SSB voice would meet the communication requirement for 5 min longitudinal separation. Considering the various points made in the preceeding sentences and the unavailability of the resources that would be required to re-estimate costs and re-document Configurations 8 and 9 with direct communications, (and noting that Configuration 14 already is an approximation, albeit not exact, of Configuration 9 with direct communications), the Committee decided to let Configurations 8 and 9 stand as established with the following caveat: "The utilization of 5 min longitudinal separation, if communications are limited to HF SSB voice, may under some conditions require more frequent position reporting (e.g., at every 5 instead of 10 degrees in longitude on pairs of aircraft separated at or near the longitudinal minimum). This, in turn, means increased controller, radio operator, and pilot workload, the net impact of which has not been fully assessed."

S.4.4 Other Improvement Technologies

The configurations involving automatic dependent surveillance with 30 nmi/5 min/2000 ft separations, cooperative independent surveillance with 15 nmi/2 min/2000 ft separation, and related technological combinations and derivatives all show a net total cost savings in Table S-1. The savings are due to the decreases in user and provider operating costs which offset the increases in the user and provider capital costs for the improvements. The user operating costs decreases are due to reduced flight costs, while the provider operating cost decreases are due to reductions in HF voice communication facilities costs (which offset provider operating costs associated with the improvements).

The net savings shown for the cooperative independent surveillance with multiple satellite data link and voice improvement alternatives should be treated with care based on the following considerations. Because of limited data, the improvement capital and operating cost estimates for the cooperative independent surveillance with multiple satellites were based on analogies with the automatic dependent surveillance with satellite data link and voice alternative (i.e., assumed satellite sharing possibilities) rather than on an explicit system design which might require dedicated satellites. The operational implementation of cooperative independent surveillance and concurrent reduced separation minima are assumed to occur in 1995. This date may be optimistically early because of possible technical and operational complexities associated with cooperative independent surveillance. In addition, the reduced separation minima are based on concurrent employment of MNPS (Advanced) navigation techniques, for which a detailed cost analysis was not undertaken within the scope of this study effort. However, an independent preliminary analysis conducted by the International Air Transport Association estimates that the discounted user capital cost for MNPS (Advanced) is of the order of $50 million

exclusive of user operating costs. Therefore, the net total cost savings indicated in Table S-1 (and subsequent tables) for Configurations 19, 20 and 21 may be reduced by $50 million. These savings might further be reduced due to a potential increase in user operating costs for MNPS (Advanced), but data has not been obtained describing the magnitude of such an increase (if any) relative to the navigation systems operating costs associated with the alternative configurations. Note that no user capital cost estimates for on-board navigation equipment have been allocated to meet MNPS (Improved), but this approach may be considered reasonable since there is a belief that current generation systems when properly assessed could provide the required navigation performance.

The capital and operating cost estmates made for these potential improvements were based on a number of data sources and a variety of assumptions addressing technical components, each of which introduce a degree of uncertainty into the cost estimates. Revisions to these cost estimates will affect net savings. Therefore, an examination of the sensitivity of the net total cost savings to parametric adjustments to some key component costs is appropriate and is addressed in the following paragraphs.

S.4.5 Aircraft Fleet Size

For the purposes of sensitivity analyses, a 20% and a 40% reducton in fleet size and avionics unit purchases are assumed relative to the original estimates. The impact on net total cost savings due to the corresponding reductions in user avionics capital costs is presented in Table S-2, which shows that the 20% reduction in avionics purchases further increases net savings by 4% to 26% depending on the configuration examined, and that the 40% reduction further increases net savings by 8% to over 50%.

S.4.6 User Avionics Capital Costs

Apart from fleet equippage considerations, the user avionics purchase costs may vary from those originally estimated. Therefore, a sensitivity analysis was performed. As shown in Table S-2, a 20% increase in user avionics capital costs reduces net total cost savings by 4% to 26%, and a 40% cost increase reduces net savings by 8% to 50% depending on the configuration examined.

S.4.7 Provider Improvements Capital Costs

The estimation of ground station costs for the automatic dependent surveillance with network HF data link and voice configuration involved many variables (e.g., land, software, hardware costs). The uncertainties in these costs might cause a 50% increase in the provider capital cost estimate relative to the original estimate. Table S-3 shows that a 50% increase in the network HF and simple network HF data link and

Table S-2

NAT NET SAVINGS RELATIVE TO BASELINE FOR VARIATIONS IN USER AVIONICS CAPITAL COST
(1979 Discounted US $ Millions)

Configuration	Original Estimate	User Avionics Capital Cost Factor* -40%	-20%	+20%	+40%
10. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	150	172(+14%)	161 (+7%)	140(-7%)	129(-14%)
11. Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	101	135(+34%)	118 (+17%)	84(-17%)	67(-34%)
12. Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1987 through 2005	18	28(55%)	23(+26%)	14(-26%)	9(-50%)
13. Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30 nmi/5 min/2000 ft in 1993 through 2005	154	171(+11%)	162(+5%)	145(-5%)	136(-11%)
14. Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005	104	135(+30%)	120(+15%)	89(+15%)	73(+30%)
15. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	145	170(+17%)	158(+9%)	132(-9%)	120(-17%)
16. Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	96	134(+40%)	115(+20%)	77(-20%)	57(-40%)
17. Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	179	197(+10%)	188(+5%)	170(-5%)	162(-10%)
18. Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	130	160(+23%)	145(+12%)	115(-12%)	100(-23%)
19. Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005	187	207(+11%)	197(+5%)	177(-5%)	166(-11%)
20. Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane, 15 nmi/2 min/2000 ft in 1995 through 2005	253	274(+8%)	263(+4%)	243(-4%)	233(-8%)
21. Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 1994 and 15 nmi/2 min/2000 ft in 1995 through 2005	214	234(+10%)	224(+5%)	203(-5%)	193(-10%)

*Value in parentheses is the percent change in net total cost saving relative to the original estimate and is subject to roundoff effects.

Table S-3

NAT NET SAVINGS RELATIVE TO BASELINE FOR SELECTED PROVIDER CAPITAL COSTS
(1979 Discounted US $ Millions)

	Configuration	Original Estimate	Provider Capital Cost Increase*
10.	Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	150	145 (-3%)†
11.	Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	101	96 (-5%)†
12.	Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1987 through 2005	18	16 (-11%)†
13.	Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30 nmi/5 min/2000 ft in 1993 through 2005	134	131 (-2%)†
14.	Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005	104	102 (-2%)†
15.	Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	145	98(-32%)§
16.	Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	96	49(-49%)§
17.	Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	179	118(-34%)§
18.	Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	130	69(-47%)§
19.	Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005	187	65(-65%)§§
20.	Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane, 15 nmi/2 min/2000 ft in 1995 through 2005	253	131(-49%)§§
21.	Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 1994 and 15 nmi/2 min/2000 ft in 1995 through 2005	214	92(-57%)§§

*Value in parentheses is the percent change in net total cost saving relative to the original estimate and is subject to roundoff effects.

†50% increase in network HF and simple netowrk HF ground station capital cost, excluding feasibility study and engineering design costs.

§50% of dedicated aeronautical space segment provider capital cost.

§§100% of dedicated aeronautical space segment provider capital cost.

voice-based Configurations 10 through 14 cause a 2% to 11% decrease in net total cost savings. This modest impact is due to the small proportion of total outlays accounted for by the provider ground station costs, which are part, not all, of the provider capital costs for this configuration (other provider capital costs are required for controller displays and automation).

The satellite segment cost estimates were based on an assumed idealized sharing of satellite and launch costs with other users. This assumed that the aeronautical system providers would fund the development of a transponder, would find a satellite with just the available capability to include this transponder, and would consequently fund the integration and launch of this transponder onboard the satellite. This assumption resulted in the allocation of 25% of the full capital costs associated with the smallest practical satellite to the aeronautical systems under consideration. However, since an ideal sharing arrangement may not be possible (i.e., a larger portion than needed of a satellite may only be available), the space segment for the automated dependent surveillance with data link and voice or the data-only systems could cost the aeronautical service providers more than is assumed by the above idealized sharing arrangement. Satellite location and service requirements associated with multiple satellite cooperative independent surveillance may well dictate a space segment implementation totally dedicated to aeronautical service. These considerations led to the sensitivity analysis shown in Table S-3 where: (1) Configurations 15 through 18 assume 50% of the capital costs of a dedicated satellite operation; and (2) Configurations 19, 20 and 21 assume 100% of a dedicated aeronautical satellite operation. Table S-3 shows that the 50% cost sharing arrangement causes a 32% to 49% decrease in net savings for Configuration 15 through 18, and the 100% dedicated satellite cost arrangement causes a 57% to 65% decrease in net savings for Configurations 19, 20 and 21. These net savings cost impacts are proportional to the portion of the total outlays accounted for by the satellite segment cost, which are part, not all, of the provider capital costs for these configurations (other provider capital costs are required for controller displays and automation).

S.4.8 ATS Facility Operating Costs

The operating and maintenance cost estimates for automatic dependent and cooperative independent surveillance functions were based on the assumption that these costs would be the same as the baseline configuration operations and maintenance costs. Since there is no precedence for an advanced air traffic control operation of the type envisaged for improved oceanic communications and no design specifications, the preliminary ATS facility operations and maintenance cost estimates were based on rough assumptions regarding controller operations. These estimates assumed that staffing, sectorization, and equippage growth would be comparable to those of the baseline configuration. Apart from this growth assumption, the estimated costs for developing

and implementing advanced ATC data handling. controller displays and associated advanced ATC automation were included. While it is not anticipated that the ATS unit operating costs will increase, a 20% increase in these costs is examined in the interest of sensitivity analysis. As shown in Table S-4, a 20% cost increase in the ATS facility component of the provider operating costs causes net total cost savings reductions of from 26% to 92% for most configurations, and more for the simple network HF data link and voice without separation minima reduction.

These large impacts on net savings are due to the significant proportion of total outlays accounted for by provider ATS operations costs. These operating costs are sizable and occur each year during the study period rather than occassionally as is typically the case with capital investments. The significant proportional reductions in net savings shown in Table S-4 for this 20% cost increase case indicates that the provider ATS operating costs exercise considerable leverage in the economic analysis results.

S.4.9 Sensitivity Analysis of Fuel Costs

The user fuel costs are based on fuel prices reported for each airport in 1979 and on a 10% annually compounded inflation rate. There is no basis to assume that the 1979 prices are in error, but the inflation rate may vary. A higher than 10% rate would increase the future fuel costs calculated for all configurations and would increase the net total cost savings associated with each improvement configuration relative to the baseline configuration. The net savings increase would improve the economic attractiveness of the alternative configurations relative to their original cost estimates, but the significance of the increased attractiveness would depend on the magnitude of fuel cost increase. Alternatively a lower than 10% rate would decrease the economic attractiveness of the alternative configurations. Therefore, the net savings resulting from 8% and 12% inflation rates are calculated as presented in Tables S-5 for the various configurations. Table S-5 shows that the 2% decrease in the fuel inflation rate to 8% causes net savings reductions of as much as 50% for the various configurations, but that the net savings remain positive for each configuration. The 2% increase in the fuel inflation rate to 12% furthers net savings to as much as 70% for the various configurations, indicating that fuel costs exercise significant influence on the economic analysis results. Note that Configuration 20 is not included in Table S-5 because the cost savings data estimated by the UK for the free vertical flight operation were not provided on a year by year basis, and, therefore, were not adaptable to the sensitivity analysis procedure used.

Table B-4

NAT NET SAVINGS RELATIVE TO BASELINE FOR A 20% INCREASE IN PROVIDER ATS FACILITY OPERATING COST
(1979 Discounted US $ Millions)

	Configuration	Original Estimate	20% Increase in ATS Facility Operating Cost*
10.	Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	150	63(-58%)
11.	Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	101	14(-86%)
12.	Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1985 through 2005	18	-69(-483%)
13.	Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30 nmi/5 min/2000 ft in 1993 through 2005	[illegible]	66(-57%)
14.	Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005	104	17(-84%)
15.	Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	145	57(-61%)
16.	Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	96	8(-92%)
17.	Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	179	92(-49%)
18.	Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	130	42(-68%)
19.	Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005	187	121(-35%)
20.	Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane, 15 nmi/2 min/2000 ft in 1995 through 2005	253	188(-26%)
21.	Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 1994 and 15 nmi/2 min/2000 ft in 1995 through 2005	214	148(-31%)

*Value in parentheses is the percent change in net total cost saving relative to the original estimate and is subject to roundoff effects.

Table S-5

NAT 1979-2005 PRESENT VALUE COST SAVINGS SENSITIVITY TO FUEL INFLATION RATE

(1979 Discounted US $ Millions)

Configuration†	Net Total Cost Savings For 10% Fuel Inflation Rate	Fuel Inflation Rates* 8%	Fuel Inflation Rates* 12%
1. Baseline, HF SSB Voice, MNPS, 120-60 nmi/15 min/2000 ft through 1980, 60 nmi/15 min/2000 ft in 1981, 60 nmi/10 min/2000 ft in 1982 through 2005	0	0(0%)	0(0%)
2. 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 2005	78	62(-21%)	101(+29%)
3. 60-30 Composite, HF SSB Voice, MNPS (Improved) and/or improved vertical performance, 60-30 nmi/10 min/2000 ft in 1985 through 2005	78	62(-21%)	101(+29%)
4. 1000 ft Vertical Separation Above FL 290 Oceanic Only, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005	448	330(-26%)	612(+37%)
5. 1000 ft Vertical Separation Above FL 290 Oceanic Only With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005	387	274(-29%)	544(+41%)
6. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005	609	450(-26%)	830(+36%)
7. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005	528	377(-29%)	740(+40%)
8. Airborne Separation Assurance Device With 100% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	102	55(-46%)	169(+66%)
9. Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	134	86(-36%)	201(+50%)
10. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	150	103(-31%)	217(+45%)
11. Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	101	54(-47%)	168(66%)
12. Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1987 through 2005	18	18(0%)	18(0%)
13. Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30 nmi/5 min/2000 ft in 1993 through 2005	154	111(-28%)	215(+40%)
14. Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005	104	62(-40%)	165(+59%)
15. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	145	98(-32%)	212(+46%)
16. Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	96	48(-50%)	163(+70%)
17. Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005	179	132(-26%)	246(+37%)
18. Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005	130	83(-36%)	197(+52%)
19. Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005	187	118(-37%)	287(+53%)
21. Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 1994 and 15 nmi/2 min/2000 ft in 1995 through 2005	214	141(-34%)	318(+49%)

*Value in parenthesis is the percent change in net total cost saving relative to saving shown for the 10% fuel inflation rate, and includes roundoff effects.

†The baseline system and separation minima are assumed in operation for each configuration until the further reductions indicated for the other configurations are achieved.

S.5 CEP Configurations and Cost Comparisons

The ATS system operating characteristics in the CEP are similar to those of the NAT, and include the use of HF SSB voice air-ground communications with a radio operator relay, long-range navigation techniques, and control procedures based on pilot voice position reports. Therefore, the CEP is ammenable to the same types of potential improvements identified for the NAT. The improvements addressed include: 1000 ft vertical separation above FL 290 in oceanic only airspace, and in oceanic and domestic airspace, with and without improved altimetry; separation assurance device with 100% and 50% avionics capital cost allocation; automatic dependent surveillance with network HF data link and voice; and automatic dependent surveillance with satellite data link and voice. These improvements are not a complete listing of all potential CEP implementations, but were selected for the purpose of providing general guidance concerning the economic impacts of the basic systems subject to the limitations of study resources.

The CEP potential improvements were assumed to be implemented in coordination with corresponding NAT implementations, although the various improvements could be developed and established independently of NAT applications. Improvement development costs were allocated to NAT operations, and CEP improvement cost estimates consisted of establishment and operating expenses. These estimates were based on engineering analysis and analogy with the corresponding NAT improvements. The FCM was used to estimate user flight costs.

Potential improvement configurations were identified based on the implementation schedules defined for the NAT. A baseline configuration was used to represent continuation of the present system technology. A comparison of the user and provider capital and operating present value costs, relative to baseline system operation, and for each configuration during the 1979 through 2005 study period, yielded the net total cost savings and component cost increments presented in Table S-6. The total cost savings shown in this table are less than those estimated for the NAT improvements because of lower traffic activity and smaller scale improvements in the CEP. However, the net savings for each improvement configuration are significant and are subject to the discussions presented in preceding paragraphs for the NAT improvements.

S.6 CAR Configurations and Cost Comparisons

The CAR represents a different ATS operating environment from the NAT and CEP. The existance of island and continental coastal land sites enable coverage in parts of the CAR by line-of-sight very high frequency (VHF) air-ground communications, radar, and ground-based radionavigation aids. However, other parts of this airspace, including gaps between the line-of-sight coverage as well as oceanic areas to the east, are covered by HF SSB voice air-ground communication services. Some of these gaps may be difficult to cover by an expansion of the line-of-sight facilities (i.e., through new ground equipment installations) because of

Table S-6

CEP 1979-2005 PRESENT VALUE COST INCREMENTS BY CONFIGURATION RELATIVE TO BASELINE
(1979 Discounted US $ Millions)

Configuration†	User Net Cost		Provider Net Cost		User and Provider Net Cost*		
	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Total Cost Saving
1. Baseline, HF SSB Voice, 50 nmi/15 min/2000 ft through 1984, 50 nmi/10 min/2000 ft in 1985 through 2005	0	0	0	0	0	0	0
2. 1000 ft Vertical Separation Above FL290 Oceanic Only, HF SSB Voice, 50 nmi/10 min/1000 ft in 1985 through 2005	0	110	0	0	0	110	110
3. 1000 ft Vertical Separation Above FL290 Oceanic Only with Improved Altimetry, HF SSB Voice, 50 nmi/10 min/2000 ft in 1988 through 2005	1	100	0	0	1	100	99
4. 1000 ft Vertical Separation Above FL290 Oceanic and Domestic, HF SSB Voice, 50 nmi/10 min/1000 ft in 1985 through 2005	0	136	0	0	0	136	136
5. 1000 ft Vertical Separation Above FL290 Oceanic and Domestic with Improved Altimetry, HF SSB Voice, 50 nmi/10 min/1000 ft in 1988 through 2005	1	125	0	0	1	125	124
6. Airborne Separation Assurance Device with 100% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990 through 2005	5	52	0	0	5	52	47
7. Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990 through 2005	2	52	0	0	2	52	49
8. Automatic Dependent Surveillance with Network HF Data Link Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990 through 2005	4	52	2	14	6	66	59
9. Automatic Dependent Surveillance with Satellite Data Link and Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990 through 2005	5	52	28	15	33	67	34

*Descrepencies in addition are due to roundoff.

†The baseline system and separation minima are assumed in operation for each configuration until further reductions indicated for the other configuration.

terrestrial constraints, and the oceanic areas could not be covered by such services. Therefore, the following potential improvements have been examined based on their ability to enhance communication and separation assurance services in the CAR: separation assurance device with 100% and 50% avionics capital cost allocation; automatic dependent surveillance with network HF data link and voice; and automatic dependent surveillance with satellite data link and voice.

The CAR improvements were assumed to be extensions of the corresponding NAT improvements to avoid cost inefficiencies, although their implementation could conceivably be conducted independently of the NAT applications. The improvement establishment and operating costs estimates were based on engineering analysis and analogy with the NAT improvements. A graphical analysis approach was used to develop rough estimates of user fuel costs due to diversions because limited available data and study resource constraints precluded the application of the FCM.

Potential improvement configurations were identified based on the implementation schedules defined for the NAT. The baseline configuration was defined under the assumption that radar coverage would be fully established in the Miami-San Juan traffic corridor, and separation minima in this corridor would be reduced to conform to radar operations in 1983. The resulting net total cost savings and component cost increments relative to the baseline are presented in Table S-7 for each configuration. This table shows that negative net savings are associated with each improvement, meaning net cost losses are estimated for each improvement configuration's implementation.

However, the potential improvements should not be dismissed simply on the basis of apparent economic liability because: (1) the improvements, (especially the separation assurance device which is shown in Table S-7 to have less of a cost loss than the other improvements) would support enhanced separation assurance services, particularly in one CAR flight information region which currently does not provide control service; (2) one or more of the improvements might be economically preferred in comparison with the alternative of expanding line-of-sight facilities; and (3) the user flight costs were roughly estimated and subject to revisions which might improve the attractiveness of one or more of the improvements. Note that, although the 1000 ft vertical separation above FL 290 improvement was not analyzed (in part because the graphical analysis approach could not evaluate the impact of vertical separation minimum reduction on user flight costs), this improvement is expected to achieve net total cost savings in the CAR based on the results obtained for analogous improvement operations in the NAT and CEP.

Table S-7

CAR 1979-2005 PRESENT VALUE COST INCREMENTS BY CONFIGURATION RELATIVE TO BASELINE
(1979 Discounted US $ Millions)

Configuration†	User Net Cost		Provider Net Cost		User and Provider Net Cost*		
	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Capital Cost Increase	Operating Cost Decrease	Total Cost Saving
1. Baseline, HF SSB Voice, 100 nmi/15-10 min/2000 ft through 1982, 100 nmi/15-10 min/2000 ft with Expanded Radar (R) Coverage in 1983 through 2005	0	0	0	0	0	0	0
2. Airborne Separation Assurance Device With 100% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005	24	1	0	0	24	1	-24
3. Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005	12	1	0	0	12	1	-11
4. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 20 nmi/5 min/2000 ft R in 1990 through 2005	20	1	-3	-34	18	-34	-51
5. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005	24	1	2	-2	26	-1	-27

*Discrepancies in addition are due to roundoff.

†The baseline system and separation minima are assumed in operation for each configuration until futher reductions indicated for the other configurations.

1.0 INTRODUCTION

This report presents the results of the OASIS project conducted by SRI International for the United States (US) Federal Aviation Administration (FAA), and describes: (1) the technology and operational issues relevant to potential system improvements to air traffic services (ATS) in oceanic and selected low traffic density areas of the world; (2) the candidate improvements that may be implemented because of worldwide needs; (3) the estimated costs of these candiates; (4) the expected costs and benefits derived from their implementation and operation; and (5) the economic, technical, and operational feasibility of implementing various system improvements in representative study areas of the world for which descriptive data are available. These areas include the North Atlantic (NAT), Central East Pacific (CEP), and Caribbean (CAR) regions. Study results are reviewed in the Executive Summary.

The study and this report are coordinated with and support the activities of the Committee to Review the Application of Satellite and Other Techniques to Civil Aviation (also called the Aviation Review Committee or the ARC).

2.0 PRESENT SYSTEM OPERATIONS AND TECHNOLOGY

2.1 Introduction

Different ATS system technologies and operational procedures currently are applied in the various world areas. The reasons for the technological differences between airspace areas range from physical constraints that have precluded system installation to economic considerations that have restrained system implementation. To provide a perspective on the issues relevant to potential system improvements, the remainder of this section addresses several pertinent technical and operational aspects of oceanic and various low traffic density areas. Additional descriptive material have been presented in companion reports (ref 1-5).

Note: The descriptions in this section of the report relate to the system operations pertaining to 1979. These descriptions do not take into account system improvements which have been implemented since and planned in the short and medium term which have and will alleviate some of the problems referred to in this section. Examples of such improvements in the NAT are:

(1) Implementation of flexible tracks between Northern Europe and the CAR.

(2) Implementation of amended position reporting procedures, to alleviate air traffic control (ATC) system loop errors.

(3) Implementation of procedures for preplanning clearances of step climb.

(4) Very significant but unquantifiable improvements resulting from phased implementation of automatic data handling and display throughout the region by 1990.

2.2 Oceanic Areas

2.2.1 Technical Systems

The communication (COM), navigation (NAV) and surveillance systems used in the oceanic ATS environments of the world, as exemplified by the NAT and CEP, are somewhat different than those used in many domestic areas. This difference is due in part to limitations on the service range of the domestic systems and the lack of suitable facility land site locations in the oceanic areas. For example, domestic air-ground

voice communications between pilots and ATS units are normally conducted by means of very-high frequency (VHF) short-range systems; short-range ultra-high frequency (UHF) is used by some military operations. These systems, although quite adequate for domestic ATS purposes, cannot satisfy the long-range transmission requirements of an oceanic operation. Instead, a high frequency (HF) radiotelephony system is used in which COM stations, rather than ATS units (which typically are not HF equipped), conduct long-range communications with over-ocean aircraft.

Ground-ground communications (i.e., point-to-point) between ATS units generally are conducted by voice through ATS direct speech circuits and by teletype through aeronautical fixed telecommunications network (AFTN) circuits. The ATS direct speech and AFTN systems in the oceanic areas are integrated with those in use in other areas and are part of multiregional interfacility communication networks. In some cases, ATS units are connected by computerized data links.

Aircraft navigation in domestic airspace normally uses such short-range ground-based systems as the VHF omnidirectional range (VOR) with distance measuring equipment (VOR/DME) radionavigation aids or the non-directional beacon (NDB) aids with automatic direction finding (NDB/ADF) equipment. Neither the VOR/DME nor the NDB/ADF systems can meet the long-range navigation requirements of the transoceanic flights. Long-range navigation commonly is accomplished by such means as inertial navigation systems (INS), Omega, and doppler radar.

The secondary surveillance radar (SSR) and primary radar systems used in domestic areas are not capable of long-range surveillance. No equivalent technology is currently employed for oceanic surveillance purposes. Flight monitoring is based on pilot voice radio reports of aircraft positions derived from on-board navigation systems.

2.2.2 Operational Issues

The existence of technological differences between the oceanic and domestic airspace operations does not mean that safety is compromised in the oceanic areas. In fac the safety record is superb. The oceanic operational procedures, interfacility coordination processes, and separation rules are based on existing navigation, communication and surveillance capabilities, and are designed to provide aircraft with separation assurance and emergency servi-es. However, the more limited capabilities of oceanic area systems require the application of operational rules and procedures that are generally more restrictive in terms of flight operational flexibility than those of the domestic areas. The relatively restrictive nature of oceanic operations increases the operating costs experienced by the users of these systems. Hence, greate efficiency of operations while maintaining or enhancing safety are the p ary objectives of potential improvements in those oceanic areas typi d by the

NAT and CEP. The following paragraphs briefly review various salient interrelated operational issues relevant to oceanic system efficiency. These issues address:

(1) Separation minima
(2) Flight planning
(3) Route structures
(4) Vertical flight profiles
(5) Organized track systems placement accuracy
(6) Oceanic entry congestion
(7) Oceanic track crossings and mergings
(8) Clearance decision making
(9) Step climb requests
(10) Aircraft speed differences
(11) Air-ground communications delay
(12) Provider operations and maintenance costs

Separation Minima--Separation minima are based on the spacings considered to be safely achievable with specific communication, navigation, and surveillance technologies. Lateral and longitudinal separation minima are strongly dependent on: the ability of aircraft to maintain assigned course; the ability of ATS systems to detect aircraft deviations from assigned position, heading and speed; and the ability of the ATS system to intervene and (1) correct deviations from the assigned course, or (2) adjust progress along that course. The differences between domestic and oceanic navigation, surveillance, and communications systems cause differences in the capabilities of these ATS systems to recognize and resolve potential violations of separation minima (i.e., potential conflicts). As a result, the longitudinal and lateral separation minima applied in the NAT, CEP, and analogous oceanic areas are significantly larger than those applied in domestic areas which are provided with VOR/DME or other radionavigation aids, VHF communications directly between pilot and controller, and primary and secondary radar coverage. For example the longitudinal separation minimum in an en route radar environment can be as small as 5 nautical miles (nmi) while the corresponding oceanic separation minimum can be as large as 120 nmi or more. Domestic VOR route spacing may be 8 nmi, in the United States (US), versus 60, 100 nmi or 120 nmi in oceanic airspace. Vertical separation minimum above FL 290, however, is 2000 ft in both oceanic and domestic areas because identical technology is used to maintain altitude.

Separation minima in the NAT are affectd by the Minimum Navigation Performance Specification (MNPS), which requires the system to satisfy a stipulated navigation performance standard. The navigation accuracy associated with MNPS has led to the implementation of planned reductions in the lateral separation minimum to 60 nmi in October 1980.

Flight Planning--The flight track and vertical profile requested by an aircraft operator represents the economically preferred flight plan based on the operator's analysis of meteorological forecasts, aircraft

fuel burn and flight performance characteristics, route structure requirements, aircraft estimated weight and reserve fuel requirements. Deviations from the ideal (i.e., truly optimum) flight plan implies additional direct operating costs, largely fuel costs but also crew and maintenance costs. The planned flight costs may be greater than ideal because of erroneous flight planning analysis data of which the meteorological forecast data is most subject to inaccuracy. Differences between ideal costs and planned flight costs are also due to route structures and flight level constraints that require aircraft to follow formal airways and vertical profiles that do not necessarily coincide with the theoretically optimum flight path between origin and destination.

Route Structures--The majority of the traffic flow in both the NAT and CEP fly structured sets of roughly parallel tracks, while numerous minor traffic flows in the NAT and CEP follow random tracks as well as NDB-based ATS routes in part of the NAT. In the NAT, the organized track system (OTS) between Europe and North America is set twice a day based on meteorological forecasts, once for the predominantly eastbound flow and once for the westbound flow. In the CEP, the organized route system (ORS) is fixed and serves the traffic flow between Hawaii and California. The OTS and ORS enable controllers to effectively manage and regulate the major traffic flows with the available equipment and facilities. However, because the track and flight level spacings conform to the large oceanic separation minima, the traffic service rate in the OTS and ORS airspace is modest in terms of aircraft handled per unit of airspace and unit of time.

Vertical Flight Profiles--A cruise climb flight regime, which allows a turbojet aircraft to continuously increase altitude, is a more fuel-efficient method of flying the aircraft than is the step climb regime, which requires flying a series of constant flight levels (FLs). However, controllers find it extremely difficult to track, project, and analyze multiple cruise climb trajectories in three dimensions, and subsonic cruise climb operations are not permitted in oceanic or domestic airspace. Instead, flight levels are assigned at 2000-foot (ft) intervals in high altitude en route airspace (above FL 290), and aircraft are cleared to step climb between flight levels. Standard hemispheric vertical separation rules assign the same direction to flight levels spaced 4000 ft apart although OTS and ORS tracks use one-way tracks with 2000 ft between same direction traffic. Despite the ability to climb at 2000-ft increments, the step climb procedure is an approximation to the optimum cruise climb procedure and any means to more closely replicate cruise climb profiles will reduce fuel costs.

OTS and ORS Placement Accuracy--In the NAT, the OTS is set according to minimum time track (MTT) objectives, (i.e., considerations based on meteorological forecasts) which may not coincide with the weather conditions at the time of flight. Also, OTS placement cannot satisfy the optimum flight paths between every origin and destination pair, nor does it necessarily conform to each airline's minimum fuel track preferences

(although airlines do provide their preliminary estimates of track preferences to ATS units as inputs to guide in designing the OTS). In effect, the OTS placement could have inherent deviations from the optimum flight paths.

The ORS in the CEP is fixed regardless of meteorological conditions, and flight planning for the ORS airspace is concerned with selecting an optimum ORS track and flight level. Wind conditions in this airspace normally are benign and the fixed tracks are quite suitable for efficient flight operations. However, during the winter storm season, some airlines develop random track routings that lie north or south of the ORS tracks or use only part of an ORS track; these routings indicate these airline's belief that the ORS placement is not always optimum.

Oceanic Entry Congestion--Although a range of subsonic turbojet aircraft types fly in the major traffic flow served by the OTS and ORS, the flight performance characteristics of each type are sufficiently similar to cause competition for airspace. The competition occurs even though different origin and destination patterns tend to spread the track preferences, different aircraft types and weights tend to spread the flight level preferences, and different flight conditions and analysis procedures used by the various flight planning offices tend to spread both the track and flight level preferences. These factors are not sufficient to significantly disperse the concentration of traffic on the OTS and ORS because the volume of traffic and the overriding influence of preferred winds tend to maintain an aggregate coincidence of track preferences.

The "packing" of preferred flight paths at OTS and ORS entry causes potential conflicts between aircraft requesting identical tracks and flight levels at nearly the same time. ATS personnel satisfy separation minima by issuing diversion or delay clearances as necessary, although generally at some cost to those aircraft that are diverted or delayed from their preference. Similar diversions and delays are experienced at the entry to oceanic ATS routes and random tracks, but not to the degree experienced on the busier OTS and ORS track entries.

Oceanic Track Crossings and Mergings--Random track and ATS route traffic is subject to various types of potential conflicts including: those involving random traffic attempting to join, cross, or leave the OTS or ORS; conflicts between aircraft on random tracks or on ATS routes; and conflicts involving random tracks crossing the ATS routes. In the OTS, the random track joinings and crossings are a problem because the intensity of traffic on the OTS often causes a random track aircraft to be diverted to tracks parallel but outside the OTS or to tracks below or above the OTS. Such diversions occur with sufficient frequency to cause aircraft operators to routinely file flight plans for paths under the OTS even though such flight levels are not optimum. For example, flights between Northern Europe and the Caribbean often file flight plans requesting FL290 for the trans-Atlantic flight segment crossing the OTS;

FL290 normally is a suboptimal flight level in terms of turbojet fuel burn efficiency. Flights between the Iberian Peninsula and Canada also have difficulties joining and crossing the OTS tracks, but such difficulties are alleviated somewhat when tributary tracks are designated that join the Iberian Peninsula with a southerly OTS track at midocean. Flights to and from Scandinavia have similar problems when flight conditions are such that their preferred tracks call for joining or crossing the northerly OTS tracks at midocean rather than entering the OTS at track endpoints or flying on random tracks north of the OTS.

In the CEP, random track traffic from the Pacific Northwest converges near Hawaii and causes congestion at this point. Also, the Pacific Northwest traffic is crossed by random track flights between North America and the Far East, which causes potential conflicts at midocean points that must be resolved by diversion or delay.

Clearance Decision Making--Oceanic controllers monitor flight progress by means of pilot position reports relayed through COM station radio operators and flight strip postings. The pilot position reports are given roughly once per hour and are not suitable for tactical control (i.e., minute-by-minute surveillance and intervention as is conducted in a radar environment). Instead, strategic clearances are issued that ensure conflict-free flight paths through all or parts of the oceanic airspace. Clearances issued to OTS and ORS aircraft are facilitated by the lateral and vertical separations inherent in the track structure, which enable ATS units to determine route approval or diversion or delay clearances based on the assessment of longitudinal minima.

Given the current separation minima, the present data processing capabilities and strategic control procedures are adequate for providing effective oceanic entry clearances to the OTS and ORS parallel traffic flows. However, in regard to the multidirectional traffic on random tracks, some question exists as to the capability of controllers not equipped with conflict prediction automation to precisely identify potential conflict intersections and select optimum resolution strategies. The flight strip fix postings normally do not coincide with potential conflict points, and controllers may be somewhat uncertain about the exact location and time of random track intersections. Furthermore, the flight strip information display is not readily amenable to the precise assessment of lateral separations between aircraft in the same vicinity. As a result, controllers may tend either to apply needless vertical diversions or to choose vertical diversions rather than the potentially more fuel-efficient lateral diversions, and, because of the lack of tactical information, may tend to maintain the diversions over long stretches of airspace.

Step Climb Requests--The profile of the optimum flight path of an aircraft depends on its weight, the distance it has to travel, and the weather conditions en route. If an aircraft is very heavy, it cannot reach its final cruising altitude immediately after takeoff, but must

gradually increase its altitude in discrete step climbs in current domestic and oceanic ATS systems. For flights in the NAT and CEP oceanic airspace, aircraft weights and flight distances are usually such that step climb requests are issued in the oceanic airspace.

A request for a step climb would be approved only if there were no violations of separation minima. Under conditions of light traffic, such as those on random tracks, the step climb is more likely to be approved than under heavier traffic flows such as those on the OTS or ORS during peak traffic periods.

Aircraft Speed Differences--Cruise speed differences between successive aircraft at the same flight level on the same track are accounted for at entry to the track when oceanic clearance is issued. In the case of an aircraft followed by a faster one, the entry spacing between aircraft is increased to prevent subsequent overtaking and violations of the longitudinal separation minimum at downstream points along the track. Such increased spacing restricts airspace utilization, thereby furthering diversions or delays and associated flight costs experienced by users. The impact is most severe when numerous and significant speed differentials occur, and frequently this is experienced on the OTS and ORS where closely spaced aircraft trailing each other is common. The situation is less common on the ATS routes because of lower traffic density and occurs infrequently on random tracks because such tracks rarely coincide.

Air-Ground Communications Delay--The process of relaying messages through the radio operator obviously requires more time than would be needed for direct air-ground communications between pilot and controller. Controllers have reported that the typical elapsed time between the instant of a pilot's clearance request by air-ground radio and the instant a pilot acknowledges receipt of the step climb clearance (both indicated on the hard copy teletype message) is of the order of 5 to 10 min. The relay time would delay the time at which an aircraft would receive a clearance and therefore could cause additional fuel costs in the case of an altitude climb request to a more fuel-efficient flight level. This situation is alleviated by pilots requesting step climbs sufficiently in advance so as not to create problems due to communication delay, provided controllers have the ability to know other aircraft positions.

Provider Operations and Maintenance Costs--The oceanic ATS units and COM stations and their associated staff and facilities incur operations and maintenance expenditures. Because expenses typically are not as high as those of large-scale domestic ATS systems, the oceanic operations and maintenance expenses are not considered to be excessive. However, the future use of the existing systems entails continuation of the current expense patterns or growth in these expenses. These future expenses may become a burden as traffic grows and the current system is expanded to meet this growth. This postulated cost growth is due to the

labor-intensive ATS and COM system operations, which may require additional staffing, and to the continued costs of maintaining technologies that were not designed according to modern cost-efficient maintenance practices.

2.3 Low Traffic Density Areas

2.3.1 Technical Systems

Many low traffic density areas of the world are not as strictly constrained by a lack of land sites as are the purely oceanic areas. Domestic technologies are used in such low traffic density areas as the Africa (AFI) and CAR regions, but the typical current state of deployment of the technical facilities is such that complete coverage by domestic systems is not realized.

In the CAR, for example, VHF air-ground communications are used when aircraft are in range of transmitters and receivers located on various island or continental coastal sites. HF radiotelephony is used when aircraft are in gaps between VHF coverages. The HF air-ground communications usually are conducted through COM stations because most (but not all) ATS units in the CAR are not HF equipped.

Ground-ground communications between CAR ATS units generally are conducted by voice through ATS direct speech circuits and by AFTN circuits. ATS direct speech interphone connections are established between most (but not all) adjacent ATS units while the AFTN connects all units. However, AFTN telegraph transmissions between any of the various ATS units in the CAR involve circuitous routings and are subject to significant delay and interruption; as a result, ATS direct speech is the primary means of communication between units. Computerized data processing systems that are used in some domestic areas are not used extensively in CAR.

NDB/ADF systems are used extensively to navigate many of the routes through CAR airspace while VOR/DME is available in some parts of the CAR. Long-range navigation using such systems as INS, Omega or doppler radar is used in those areas that are beyond NDB or VOR coverage.

Currently, a limited number of radar sites provide coverage in parts of the CAR, but the coverage is not extensive.

2.3.2 Operational Issues

In low traffic density areas of interest, such as the CAR and AFI, services are provided by a diverse set of facilities. Some are similar to those of oceanic areas, and the associated operational issues of efficiency are analogous to those described above for the oceanic operations except that the severity of flight cost penalties due to congestion is not as great due to lower traffic activity. Others are standard land based ATC facilities and services. Certain other problems encountered

in some low traffic density areas are described in the following paragraphs which address:

(1) Separation Assurance Services
(2) Ground-Ground Communications Delay
(3) ATS Jurisdictions

Separation Assurance Services--Not all states within the low traffic density areas provide complete ATS service. In the CAR, the Port-au-Prince flight information region (FIR) is uncontrolled airspace in which separation assurance is not provided. In AFI, area control service is provided in various local areas (largely extensions of terminal areas) and along some ATS routes. Aircraft flying through the uncontrolled airspace are not protected from potential conflict situations by ground-based air traffic control (ATC) services. In lieu of ATC service, aircraft operators may employ precautionary procedures such as self-announced, self-initiated VHF radio broadcasts of position while flying through uncontrolled airspace. However, such procedures are not sufficiently systematic to assure cooperation and coordination between aircraft regarding collision avoidance maneuvers.

Ground-Ground Communications Delay--A safety issue could arise from the possibility of missed coordinations between those ATS units that do provide ATC service in control areas (CTAs). Delays or interruptions in the AFTN delivery of messages cause situations in which flight plans are not forwarded in a timely manner. This situation can result in a surprise intrusion (i.e., a "pop-up") by an aircraft into controlled airspace, and can cause a violation of separation minima. The possible occurrence of pop-ups is countered by air traffic controllers by routinely forwarding flight plan data by voice using the ATS direct speech service. This procedure is cumbersome, labor intensive, and subject to interruption.

ATS Jurisdictions--There are 11 FIRs in the CAR and about 30 FIRs in the AFI region. These are rather large numbers of ATS jurisdictions given their geographic extent of coverage and low traffic density, but are established by the various states in consideration of their sovereign territorial jurisdictions. Since each ATS jurisdiction includes a staff and technical facilities structure, cost efficiency would be improved if a fewer number of jurisdictions could provide ATS.

2.4 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume II: North Atlantic Region Air Traffic Services System Description." Final Report No. FAA-EM-81-17, II (September 1981).

2. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume III: Central East Pacific Region Air Traffic Services System Description", Final Report No. FAA-EM-81-17, III (September 1981).

3. SRI Internaional, "Oceanic Area System Improvement Study (OASIS) Volume IV: Caribbean Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, IV (September 1981).

4. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume V: North Atlantic, Central East Pacific, and Caribbean Communication Systems Description", Final Report No. FAA-EM-81-17, V (September 1981).

5. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume VI: North Atlantic, Central East Pacific, and Caribbean Navigation Systems Descriptions", Final Report No. FAA-EM-81-17, VI (September 1981).

3.0 POTENTIAL SYSTEM IMPROVEMENTS

3.1 Improvement Objectives

The operational issues discussed in the preceding section are used in this section as a basis for identifying potential system improvements and applications. The issues are interrelated and address various overlapping problem areas. For example, the magnitude of separation minima is highly correlated to the diversion and delay costs associated with track entry congestion, track crossings and mergings, route structuring, step climb, and speed difference issues. To facilitate the process of defining system development candidates, the following improvement objectives have been identified with the understanding that complex interactions exist between many of the items listed and that the individual items are not necessarily of equal importance (note that separation minima reduction is closely related to many of the following objectives and therefore is not specifically identified as a separate objective): improve flight planning efficiency; reduce oceanic entry congestion and diversion and delay costs; reduce crossing and merging congestion and diversion and delay costs; increase the frequency of step climb approvals; reduce spacings due to aircraft speed differences; increase route structure flexibility; improve vertical flight profiles; improve OTS and ORS placement accuracy; provide data necessary to improve the clearance decision-making process; reduce delay and improve reliability of air-ground communication; reduce delay and improve reliability of ground-ground communication; reduce ATS provider facility operations and maintenance costs; enhance separation assurance services; alleviate multiplicity of ATS jurisdictions.

This listing is not meant to be an exhaustive itemization of all possible improvement objectives, but does provide a useful reference for examining the potential for improvement in the various areas. Because many of the potential improvement applications (improved flight planning being an obvious example) are common to the various areas, consideration must be given to defining potential system improvements that have worldwide application rather than strictly regional application. The goal of worldwide applicability is supported by the efficiencies obtainable by restricting aircraft equippage to commonly used systems rather than diverse equippage requirements to satisfy different systems in various areas.

3.2 Improvement Categories

Various domestic and oceanic system improvements are under consideration for development by the ATS provider and user authorities of the world. These improvements involve a range of technical, operational

and institutional implementations, many of which (such as improved SSR) are oriented to domestic operations. After considering the various system development programs and concepts, the Aviation Review Committee has identified the following improvement categories ranked in priority order of interest for consideration in oceanic and selected low traffic density areas:

(1) Reduction of vertical separation above FL 290

(2) Airborne separation assurance device

(3) Automatic dependent surveillance and reduction of air-ground communication delay

(4) Improved air-ground and ground-ground communications

(5) Extension of the MNPS concept

(6) Better airspace utilization through use of improved and automated data handling and displays for controllers.

(7) Improved meteorological (MET) data and more efficient use of MET data

(8) Display of traffic in the cockpit based on air-air information exchange

(9) Cooperative independent surveillance and instantaneous air-ground communications.

Table 3-1 relates the improvement categories to the improvement objectives, and indicates that many of the individual candidate categories potentially can meet several objectives. For example, the reduction of air-ground COM delay and use of automatic dependent surveillance over oceans would further the objectives associated with reduced separation minima, reduced delay and diversion, increased step climbs, reduced spacings due to speed differences, improved clearance decision making, reduced air-ground and ground-ground communication delay, and reduced provider facility operation and maintenance costs. However, the capability to achieve some or all of the objectives cited in Table 3-1 depends on the specific technological and operational components of a particular system improvement. The remainder of this section describes the relevance of each improvement category to the improvement objectives and introduces the various technologies associated with each category. Note that certain technologies are interdependent, and that the technologies are not necessarily specific to given areas but are applicable to various areas of the world.

Table 3-1

IMPROVEMENT OBJECTIVES AND IMPORVEMENT CATEGORY INTERACTIONS--PRELIMINARY ASSESSMENT

POTENTIAL ABILITY TO SATISFY OBJECTIVES BY IMPROVEMENT CATEGORY

Improvement Objectives	1000-ft Vertical Separation	Separation Assurance Device	Minimize A/G COM Delay and Automatic Dependent Surveillance*	Improved A/G and G/G COM*	Extension of MNPS Concept	Better Airspace Utilization Through ADH* And Displays For Controllers	Improved MET Data and use of MET data	Display of Traffic Based on A/A Information Exchange*	Instantaneous A/G COM and Cooperative Independent Surveillance*
Improve flight planning efficiency	YES	YES	YES	-	YES	YES	YES	-	YES
Reduce oceanic entry congestion and diversion and delay costs	YES	YES	YES	-	YES	YES	-	-	YES
Reduce crossing and merging congeston and diversion and delay costs	YES	YES	YES	-	YES	YES	-	-	YES
Increase the frequency of step climb approvals	YES	YES	YES	-	YES	YES	-	-	YES
Reduce spacings due to aircraft speed differences	-	YES	YES	-	-	YES	-	-	YES
Increase route structure flexibility	-	YES	YES	-	-	-	-	-	YES
Improve vertical flight profiles	YES	-	YES	-	-	YES	-	-	YES
Improve OTS and ORS placement accuracy	-	-	-	-	-	-	YES	-	-
Improve the clearance decision making process	-	-	YES	-	-	YES	YES	-	YES
A/G communication, reduce delay and improve reliability*	-	-	YES	YES	-	-	-	-	YES
G/G communication, reduce delay and improve reliability*	-	-	-	YES	-	-	-	-	-
Reduce ATS provider facility operations and maintenance costs	-	-	YES	-	-	-	-	-	-
Enhance separation assurance services	-	YES	-	-	-	-	-	YES	-
Alleviate multiplicity of ATS jurisdictions	-	-	-	YES	-	-	-	-	-

*A/G = air-ground; G/G = ground-ground; A/A = air-air; ADH = Automated Data Handling.

3.3 Reduction of Vertical Separation Above FL 290

Reduction in the vertical separation minimum from 2000 ft to 1000 ft above FL290 will achieve the following objectives: improve vertical flight profiles by enabling aircraft to follow step climb profiles that more nearly approximate the optimum cruise climb profiles; improve flight planning efficiency by providing a greater flexibility in flight level selection; reduce the penalty of oceanic entry and crossing and merging congestion by minimizing flight level diversions ; reduce diversion and delay costs by providing more alternative flight levels closer to the preferred profile; and increase the frequency of step climb request approvals by reducing traffic densities on each flight level, thereby reducing occurrences of potential conflicts.

The magnitude of the vertical separation minimum depends largely on the vertical position measuring accuracy of the aircraft altimetry system and the errors associated with altitude keeping. The barometric altimeter systems in current use are subject to three types of errors: static pressure system errors, altimeter instrument errors, and flight technical errors. The error due to the static pressure system, which senses ambient air pressure, is the difference between the true pressure altitude (i.e., true FL) and the pressure altitude measured by the static system. The error due to the altimeter instrument system, which translates the pressure sensed by the static system into flight level indication in the cockpit, is the difference between the measured pressure altitude and the altitude displayed in the cockpit. Flight technical error, which reflects the ability of the pilot or the automatic altitude hold system to maintain a desired level is the difference between the cockpit-displayed pressure altitude and the pressure altitude assigned to the aircraft (ref. 1).

The 2000 ft vertical separation minimum was established in the 1950s based on the performance characteristics of the altimetry systems then in use. Improvements in altimetry systems since 1960 have been implemented in much of the air fleet, including the turbojet aircraft capable of operating at the higher altitudes. These improvements, together with the use of autopilot vertical hold techniques which reduce flight technical error, have increased the accuracy of vertical position measurement and display in certain aircraft, but the degree of improved performance, and up-to-date standards of performance on which vertical separation standards may be based, have not been established (ref. 2).

A comprehensive data collection and study program is under consideration in the US to determine the potential for reduction of vertical separation above FL 290 to 1000 ft. This study may conclude that current systems are adequate or that further improvements are necessary. In either event, the reduced vertical minimum, if achieved, might be applied to domestic and oceanic airspace. However, another outcome could find that a new system such as radar altimetry, would be needed. In such a case, the 1000 ft vertical separation minimum might be limited to oceanic operations.

3.4 Airborne Separation Assurance Device

An airborne separation assurance device would form the basis for a collision avoidance system that provides the capability for aircraft to recognize and resolve certain potential conflict situations otherwise undetected by the ATC system. A separation assurance device used in controlled airspace could detect potential conflict situations that occur as a result of aircraft deviating from the assigned position and course without detection and intervention by the control system. Such situations are infrequent and their rate of occurrence is related to the density of traffic and to the characteristics of the tails of the probability distribution curve describing the system navigational performance characteristics. Since the operation of this device would prevent the effects of the tails of the system navigation performance characteristics curve from increasing collision risk, the term "tailcutter" has been used to describe this device. Such devices may also offer a capability for air-derived collision avoidance in areas where separation services may not be currently provided by ground-based systems.

Because the airborne separation assurance device protects against potential conflicts that would not be detected and resolved by the current ATS systems in the areas under study, the device would decrease the collision risk potential of the ATS systems and therefore might allow reduction of lateral and longitudinal separations where those standards are established in consideration of the incidence of large errors. Such a reduction of separation minima would improve flight planning accuracy and reduce congestion, diversion, and delay because of the increased availability and flexibility of preferred and alternate routings due to closer spaced tracks and closer longitudinal aircraft spacings. These capabilities are the basis for the potential improvement impacts shown in Table 3-1, which specifically identify reduced oceanic entry and crossing and merging congestion, reduced diversion and delay costs, increased frequency of step climb approvals, and reduced spacings due to aircraft speed differences.

The airborne separation assurance device could be operated in oceanic and selected low traffic density areas without dependence on external control systems. It would operate independently of ground-based, satellite-based, or other support systems, and therefore would not require the existence or implementation of support facilities. The consideration of this potential improvement in this study is focused on aircraft equipment installations that provide active air-to-air interrogations and data transmissions between proximate aircraft, as well as providing potential conflict recognition, assessment, and resolution information to pilots.

A separation assurance device based upon the secondary surveillance radar could operate by interrogating transponders in other aircraft and computing range, range rates, altitude, and altitude rate of closing aircraft (ref. 3). The existence of a threat would be recognized by an

on-board computer that generates a resolution command for display to the pilot. If the bearing of the threatening aircraft is not measured, only vertical maneuver instruction and vertical speed limits would be issued. This capability could be upgraded with the addition of a directional antenna with sufficient accuracy to provide horizontal information. A directional antenna, possibly with extended range, might be used to provide position keeping capability as well as collision avoidance. A position keeping function might support close longitudinal spacing between following aircraft on identical tracks.

3.5 Automatic Dependent Surveillance Over Oceans and Reduction of Air-Ground Communication Delay

This potential improvement provides two significant capabilities: (1) minimized air-ground communication delay between pilot and controller based on digital data link and limited voice services; and (2) an automatic dependent surveillance function. Air-ground data link and voice transmission capabilities directly between aircraft and ATS units obviate the need for a COM station intermediary. This system would transmit automatically, via the data link, aircraft position reports derived from the onboard navigation system. Hence, the position data is dependent on the aircraft avionics, in contrast with a ground-based SSR-like cooperative independent surveillance service. The dependent surveillance and associated communication improvements would provide position reports more frequently than does the current HF voice operation and would enable more rapid response by controllers to aircraft situations requiring intervention. This improvement would be used in conjunction with automated ATC data handling, displays for controllers and associated advanced ATC automation. The resulting improvements in surveillance and communication might support reduced lateral and longitudinal separation minima, although the reductions would not be as large as those associated with cooperative independent surveillance. Such reductions in separation minima would support objectives associated with reducing congestion, diversion, and delay, and related impacts indicated in Table 3-1 for this system. The reduced dependence on COM station facilities could enable reduction of provider operation and maintenance costs.

Various technologies have been considered for implementing automatic dependent surveillance and associated communication improvements, including HF data link and voice, satellite data link and voice, terrestrial relay (e.g., oceanic platforms), air-to-air relay between system users, and drone aircraft relay (ref. 4). Based on technical, operational, and economic considerations, the simple network HF, network HF and satellite systems appear to be the most promising candidates for further evaluation and are introduced in the following paragraphs.

3.5.1 Simple Network HF Data Link and Voice

HF relies on ionospheric propagation and is subject to ionospheric disturbances that interfere with message transmissions. The resulting outages generally are local in nature and do not normally affect all

available frequencies and locations (i.e., all transmission paths). Pilots experiencing voice transmission difficulties using the current HF system can search for and transmit on a more usable frequency, possibly to another ground station. Also, current voice messages received at ground stations other than that addressed can be copied and forwarded by AFTN to the addressed station. This networking procedure, and the use of air-to-air VHF voice relay, provides a method for completing air-ground communications with a ground station whose frequencies are experiencing outage difficulties.

Comparable networking procedures could be provided for (depending on design as discussed below) by the simple network HF data link concept. If the occurrence of outages were not detected and effectively counteracted by this system, the resulting unreliable and irregular transmission performance characteristics inherent in a simple network HF data link system concept would probably not support a reduction of separation minima. However, even though many unknowns are associated with accurately estimating the performance improvement (and associated overall system impacts) of changing from an HF voice to basically an HF data link air-ground communication environment, several functional improvements are evident: (1) Direct pilot-to-controller communications may be established. Inherent in this development would be a reduction of air-ground communications delay by eliminating the present system message copying and associated transfer delays. (2) Data Link would provide the means with which to initiate an automatic dependent surveillance function. This function, coupled with automated ATC data handling, controller displays and associated advanced ATC automation improvements, would allow the controllers to more efficiently make use of airspace. (3) The basic HF data link signal format and associated coding possibilities would make HF data link more reliable than HF voice. In addition, the ease with which data link messages might be automatically retransmitted several times over a relatively short time period (should there be propagation difficulties) would also enhance reliability and reduce message transmission delay. A reduction in the radio operator labor intensiveness also would occur.

An evolutionary transition to a reduction of separation minima to 30 nmi/5 min/2000 ft is considered as an option associated with the simple network HF data link and voice system; experience and tests associated with an initial system would determine if such a system (without an airborne separation assurance device) would have the link reliability to support a minima reduction.

A simple network HF data link concept has been designed by Working Group B of the Aviation Review Committee as a relatively low cost, evolutionary means for improving communications (see Section 5 and Appendix A of this report). This concept essentially involves establishing HF data link capabilities at the present HF COM and ATS ground facilities and on aircraft, and providing upgraded data links between ground facilities. This concept by design involves moderate aircraft

position polling rates and moderately sized data link mechanisms for coordinating the HF operations between the participating ground stations. The COM stations (e.g., six in the NAT) would be connected in a real time network with polling centrally controlled by a master control station (e.g., in the NAT, from either one of two master control stations, one in North America and one in Europe) not necessarily collocated with a COM station. One family of five HF frequencies is assumed to be used with an average position update interval of 5 minutes (ref. 5). It is assumed that a simple network HF data link and voice system would not utilize as systematic a sounding or probing scheme of the HF spectrum and the extensive frequency switching as the more sophisticated network HF data link and voice system design discussed in Section 3.5.2.

This simple network HF data link and voice design retains a level of communication link reliability that is better than or as a minimum at least as good as the present HF SSB voice system. In this simple network system design, air-ground data link communication messages and position reports could be transmitted to alternative ground stations and subsequently automatically data-linked (via ground-ground links) back to the ATS ground station handling the aircraft. Likewise, a capability would be available to automatically attempt communication through the alternate ground stations available. Note that the above described simple network HF data link and voice concept as proposed by Working Group B is a more integrated and systematic concept than a previously proposed (ref. 6) and simpler non-network HF data link and voice concept which could have included interlinked ground facilities, but not the systematic sounding or probing of the HF spectrum, or the master control and associated networking of the simple network concept. The non-network concept, as considered by the Aviation Review Committee, is not expected to provide a the level of reliability and flexibility in continuous performance as the simple network design. The possibilities for networking and the associated increased level of expected performance make the simple network HF system a candidate for implementation in such areas as the NAT. The possible suitability of a non-network HF data link system to areas where networking may not be possible would depend on such factors as the system's objectives (e.g., to establish direct pilot-to-controller communication, or to provide for an increased frequency of position reports without increasing labor intensiveness), the potential link reliability, frequency availability, and costs.

3.5.2 Network HF Data Link and Voice

A highly reliable HF air-ground data link and voice communication system requires a carefully structured and integrated network of radio facilities, equipment, and procedures to select and assign usable frequencies at all times. Working Group B of the Aviation Review Committee has determined that HF data link propogation difficulties might be overcome to the extent necessary by applying the full set of advanced HF communication techniques believed to be workable (see Section 5 and Appendix A of this report). The proposed approach includes the joint

application of HF frequency, spacial path, and time diversity techniques for signal transmission. Frequency diversity involves probing or sounding of the HF frequencies over the allocated spectrum to select the optimum frequency for a specific air-ground transmission at a specific time. Spacial path diversity involves the simultaneous transmission of messages over multiple links. Time diversity involves an intricate signal modulation design using correcting codes and message interleaving to provide adequate transmission capacity.

The sounding technique is the central element of the proposed system concept and requires strict coordination between the various system participants (i.e., ATS units) to assure proper HF channel management. This coordination requires a high grade ground-ground communication network (e.g., leased satellite circuits) between the participating facilities to enable proper command and control of the HF data link operation. Despite the elaborate structure of the proposed HF system, insufficient information on empirical HF propogation is available to guarantee that a large-scale ionospheric disturbance would not interrupt service to an unacceptable level.

3.5.3 Satellite Data Link and Voice

While the network HF data link and voice system is a case where all available engineering concepts would be called upon to develop a reliable air-ground communication service, the currently attainable satellite data link and voice technology is expected to be capable of providing the data transmission rates and area coverage required for ATS communication purposes. However, the cost of providing satellite service could be high and judgement must be exercised to limit expenditures to levels commensurate with the needs of the aviation community. The costs are quite sensitive to the satellite voice communication requirement, which is much more costly than the satellite data link function.

Working Group B of the Aviation Review Committee has developed proposed satellite data link and voice system concepts based on L-band aircraft/satellite communications (with allowance for VHF aircraft/satellite communications as an alternative), and C-band for the ground/satellite portions of the air-ground communications and the ground-ground communications for command and control of the air-ground operation (see Section 5 and Appendix B of this report). A single satellite communications package with another back-up package in orbit would be required to provide the air-ground communications reliability. Various approaches could be envisioned for providing the space segment including: (1) leasing channels from a commercial service; (2) putting a small aviation transponder package on an available satellite, and sharing the satellite costs; and (3) developing and supporting a satellite system designed specifically for and dedicated to aviation applications (an action that would provide complete control over the services provided but at a high cost of financing the entire satellite, subject to channel subleasing arrangements). As presented in Section 5.3.2, option (2)

above was used as the basis for estimating costs. Similarly, the ground component of the system may be based on leased, shared, or owned equipment and support facilities. The airborne component will require on-board installation of compatible radio, antenna, and data processing equipment.

3.6 Improved Air-Ground and Ground-Ground Communications

Improved air-ground and ground-ground communications--or equivalently improved aeronautical mobile service and aeronautical fixed service--includes the application of advanced techniques such as the use of HF and satellite data link techniques introduced in the preceding paragraphs or the expansion of currently available domestic communication technologies. In either case, a main objective is to improve and integrate overall ATS communication service (as shown in Table 3-1) and thereby support the implementation of other potential system improvements. An upgraded air-ground and ground-ground communications network could also foster the alleviation of multiple ATS jurisdictions, especially in an area where an excess number of jurisdictions are established because of current communications limitations. The COM network improvements would provide a broader geographic scope of air-ground coverage by a given unit and would facilitate interfacility coordination.

The ground-ground communications improvements such as expanded data link services may be readily accomplished in areas where high quality owned or leased circuits are currently available. In other areas, where the available post, telegraph, and telephone leased circuits are subject to interruptions, the adaptation of the HF or satellite data link techniques should be considered. However, the combined provision of air-ground and ground-ground communications by a common system is subject to international regulations that assign separate frequencies to aeronautical mobile and fixed services.

3.7 Extension of MNPS Concept

The extension of the MNPS concept, which currently is applied in part of the NAT, to other areas could support reductions in the lateral separation minima and related objectives associated with reduced congestion, diversion, and delay and improved flight planning accuracy as shown in Table 3-1. However, the degree to which diversion and delay costs could be meaningfully reduced depends on the extent of congestion currently being experienced in the particular area of application. Clearly, an area with concentrated traffic flow such as the ORS in the CEP or heavily used corridors in other areas would benefit most. The extension of MNPS might require some means of assuring conformance to the navigation specification (e.g., using radar).

In conjunction with other potential system improvements, MNPS improvements could support further reductions in separation minima. For example, the accuracy of some currently used navigation systems more than satisfies the existing MNPS standard, and further improvements in

avionics would support more stringent MNPS standards and concurrent reductions in the lateral separation minimum. The MNPS concept could be expanded to cover position keeping accuracy to support longitudinal minimum reductions, as well as to cover vertical position accuracy specifications in support of a reduction to 1000 ft vertical separation minimum above FL 290.

3.8 Better Airspace Utilization Through the Use of Improved and Automated Data Handling and Displays for Controllers

This potential improvement and associated ATC automation would employ computerization to present more precise and comprehensive traffic description and analysis information to controllers than is currently provided. The automation devices would provide various capabilities including automated flight data displays, traffic situation displays, and conflict prediction and resolution. Automated data presentations operating in conjunction with communication improvements would enable controllers to more accurately assess traffic situations, especially potential conflicts, and thereby determine clearance decisions that are more sensitive to aircraft flight preferences. The improved conflict intervention capability would permit better assessment and approval of step climbs, and more efficient airspace utilization. In addition, it would support reductions in lateral and longitudinal separation minima and thus further the congestion, diversion, delay, and flight planning objectives shown in Table 3-1.

Various near-term advanced data handling, display and associated automation improvements to expand current capabilities are under development. For example, the expanded use of conflict prediction devices, one version of which has been in operation by the Gander Area Control Center (ACC), is planned in the NAT. Implementation plans also include introduction of tabular displays of flight data, conflict alerting, and automatic input and processing of position reports. These near-term improvements would support the continuation of current control operations into the future.

Quite apart from the near-term automation improvements, more sophisticated automated ATC data handling, controller displays, and associated advanced ATC automation features using direct air-ground communications are assumed to be needed to support automatic dependent surveillance and the cooperative independent surveillance functions. Tabular and graphical displays and potential conflict resolution features would enhance controller potential conflict intervention capabilities. This is assumed to include software to search for and identify specific flight technical errors (e.g., incorrect waypoint insertions by pilots) to reduce deviations from assigned course. These improvements would further tactical control and support longitudinal separation minima. These automated ATC data handling, controller displays, and associated advanced ATC automation features are assumed to be required to be used in conjunction with the following improvement alternatives: automatic dependent surveillance with network HF data link and

voice and with simple network HF data link and voice with and without separation minima reduction, automatic dependent surveillance with satellite data link and voice or with satellite data-link only, and cooperative independent surveillance with multiple satellites data link and voice.

3.9 Improved MET Data and Use of MET Data

More accurate meteorological forecasts than those currently provided clearly would improve flight planning accuracy and OTS placement accuracy as shown in Table 3-1. Improved MET data would also improve ORS placement accuracy only if this track system were adjusted daily or periodically rather than held fixed as is the current practice. Improved MET data also would increase the accuracy of flight track projections and associated conflict detection automation, thereby providing controllers with more accurate information on which to base clearance decisions.

Meteorological forecasts are based on radiosonde observations made by weather services augmented by other data observations including pilot air reports (AIREPs). The frequency and scope of geographic coverage of the AIREPs can be increased by using automated reporting procedures such as satellite-relayed air-ground data link messages. The Commercial Aircraft Fuel Savings Program of the US National Aeronautics and Space Administration (NASA) has been investigating the aviation applications and benefits of improved MET data and their use (ref. 8). Aviation programs to expand AIREP observations, however, must be coordinated with the weather services to assure that the aviation data are being considered in a satisfactory manner relative to radiosonde reports in the meteorological forecasting process. Otherwise, the aviation MET data gathering program may have limited impact on the quality of the forecasts.

3.10 Display of Traffic Based on Air-Air Information Exchange

A cockpit display of traffic information (CDTI) based on air-air transmissions could provide a pilot with information on selected traffic of concern (ref. 3,7). The air-air CDTI describes proximate traffic and therefore might be used by pilots to maintain awareness of situations and to detect potential loss of separations between cooperating aircraft. While the display does not guarantee separation between all aircraft in these areas, it could enable pilots to maintain their own spacing between suitably equipped aircraft and therefore is considered a basis for self-separation in low traffic activity areas where separation service may not be provided. (See Table 3-1.) Furthermore, in systems providing ATC services, the utilization of conditional clearances might be facilitated with CDTI.

The airborne CDTI requires implementation of airborne electronic display, computer processing, and interrogation and receiver equipment. The operation would be similar to that of a separation assurance device (and could operate in conjunction with such a device), except that the

CDTI would not generate conflict detection and avoidance information. The CDTI data acquisition and processing system would not necessarily provide the level of precision required to support collision avoidance, but would provide sufficient display resolution to enable the pilot to remain aware of the traffic situation (ref. 3).

3.11 Cooperative Independent Surveillance and Instantaneous Air-Ground Communication

This improvement concept includes the communications capability necessary to support a cooperative independent surveillance function, and digital data link and voice link services directly between aircraft and ATS units, and thus eliminates the requirement for a COM station relay. This improvement would automatically interrogate aircraft transponders and process the response data to provide SSR-like cooperative independent surveillance. This improvement used in conjunction with automated ATC data handling, controller displays and associated advanced ATC automation would enhance tactical intervention capabilities and support significant lateral and longitudinal separation minima reductions and associated congestion, delay, diversion, and flight planning impacts as shown in Table 3-1 for this system.

The cooperative independent surveillance function would require multiple satellites to provide the interrogation data needed to determine aircraft position. For example, time-difference ranging techniques may be used to calculate aircraft positions independently of airborne navigation systems. The multiple satellite system would require at minimum two active space vehicles and one spare vehicle in orbit. The resulting high implementation costs (particularly if the satellites are dedicated to aeronautical rather than shared services) would be a critical determinant of the economic feasibility of this system.

3.12 References

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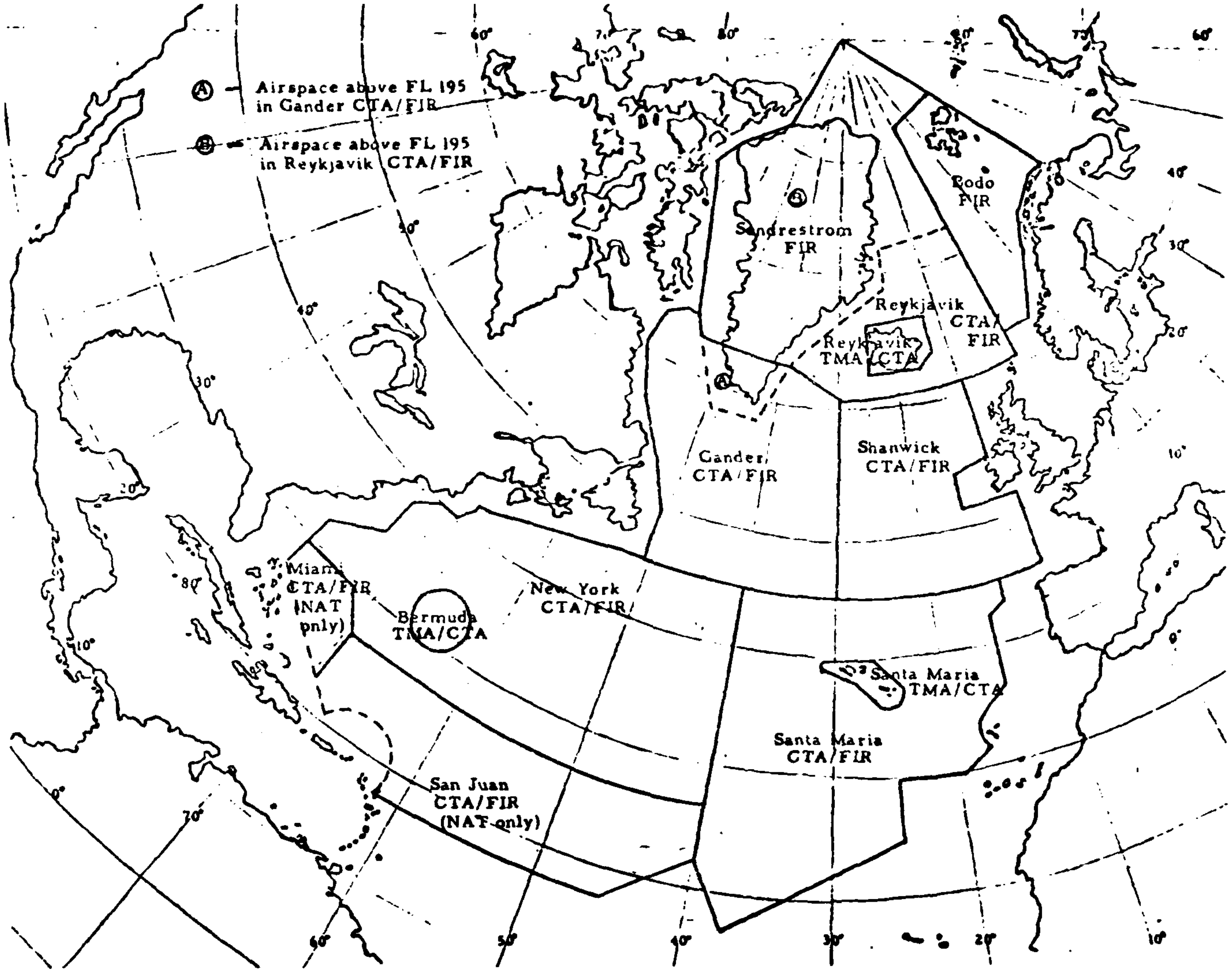
4.0 NAT OPERATING REQUIREMENTS

4.1 Introduction

The previous section identified numerous improvement objectives, many of which have the common goal of achieving reduced separation minima, and identified various potential improvements that would support separation minima reductions. However, the underlying justifications for considering these reductions were not elaborated. This section describes the ATS system operating requirements for separation minima reductions for the pertinent potential improvements in the NAT. While this section addresses the NAT, the general discussions and conclusions are considered relevant to other similar areas of the world.

The NAT, for the purposes of this report, is the high altitude enroute airspace shown in Figure 4-1 and includes the Gander, Shanwick, New York, Santa Maria and Reykjavik CTA/FIRs, and part of the San Juan and Miami CTA/FIRs. This NAT airspace includes traffic flows whose operations would be impacted by potential oceanic system improvements, and includes trans-Atlantic traffic operating between Europe and North America as well as traffic operating only in certain parts of the North Atlantic (e.g., oceanic flights in the western North Atlantic operating between the Caribbean/South America area and the northeastern United States/Canada). The NAT airspace shown in Table 4-1 is in general larger than the areas addressed by other organizations such as the North Atlantic Traffic Forecasting Group (NAT/TFG), and therefore encompasses greater traffic volumes than those addressed by the NAT/TFG and others. For example, the NAT airspace addressed in this report covers the following traffic flows, of which the last five (items 10 through 14) are understood not to be included in the NAT/TFG traffic sample:

1. Scandinavia-North America
2. Europe-Eastern North America
3. Europe-Mid North America
4. Europe-Western North America
5. Europe-Caribbean
6. Iberia-USA
7. Iberia-Canada
8. Iberia-Caribbean
9. North America-Africa
10. Europe-Iceland
11. Europe-Azores
12. US/Canada-Caribbean/S. America
13. Mideast/Africa-Caribbean/S. America
14. Greenland-USA/Canada



Source: ICAO Doc 8775/10, ANP-NAT/NAM/PAC (Sep 1977)

FIGURE 4-1 NAT AIRSPACE

Table 4-1

REQUIREMENT/SEPARATION GUIDELINES DEVELOPED BY THE AVIATION REVIEW COMMITTEE

Separation Minimum	Requirements: Air-Ground COM	2 Sigma NAV	Automatic Surveillance	Airborne Separation Assurance Device	Earliest Time Scale	Annotations
60 nmi	HF SSB Voice	MNPS	No	No	Oct. 1980	-
60-30 nmi composite	HF SSB Voice (1)	MNPS	No	?	1985	(1) Assumes more rapid ground handling
60-30 nmi composite	HF SSB Voice (1)	MNSP (1) and/or improved vertical NAV performance	No	No	1985	(1) See above
30 nmi	HF SSB Voice	MNPS (7)	No	Yes	-	-
30 nmi	Direct†	MNPS (I)	Yes (4)	No (7)	-	(4) Assumes best dependent surveillance defined as: automatic readout of navigation data and transmission to and presentation to the controller without human intervention, possibly with supplemental information from the pilot when required. (7) Airborne Separation assurance device might be perceived to be required in conjunction with dependent surveillance
<30 nmi	Direct†	Super MNPS	Dependent	Yes		(8) The extent below the 30 nmi minimum to which this alternative might be applied has not been considered.
<30 nmi	Direct†	Super MNPS (2)	Independent (2)	No (3)	1995	(2) NAV/Surveillance interaction (3) Where surveillance is adequate
15 min	HF SSB Voice	No	No	No	Current	-
10 min	HF SSB Voice	PS	No	No	1981	-
5 min	Direct†	PS (I)	Yes (4)	No	1990*	(4) See above
5 min	Direct/HF SSB Voice§,†	PS (I)	No	Yes (5)	1990*	(5) With station keeping facility added.
<5 min	Direct†	Super PS	Yes (4)	Yes	1995	(4) See above (9) The extent below the 5 min minimum to which this alternative might be applied has not been considered.
<5 min	Direct†	Super PS	Independent	No	1995	-
1000 ft	SSB Voice	MNPS (V)	No	Yes (6)	1985	(6) Airborne separation assurance device may or may not be required.

*Date assumes institutional arrangements permit.

†Direct communications, for the purposes of this study, is defined to be communications between pilot and controller without the intervention and services of a radio operator (communicator) intermediary, such as might be provided by HF data link, satellite data link and/or voice link, or VHF data link and/or voice link where coverage is available.

§The utilization of 5 min longitudinal separation, if communications are limited to HF SSB voice, may under some conditions require more frequent position reporting (e.g., at every 5 instead of 10 degrees of longitude on pairs of aircraft separated at or near the longitudinal minimum). This, in turn, means increased controller, radio operator, and pilot workload, the net impact of which has not been fully assessed.

Source: Aviation Review Committee (ref. 1) with amendments (ref. 2).

4.2 Separation Minima Reductions

The separation minima reflect the operating capabilities of the navigation, surveillance, and communication systems, as well as potential conflict intervention procedures, expressed in terms of the abilities of the systems to jointly support separation assurance service. Separation assurance in controlled airspace depends in part on the ability of aircraft to maintain assigned position and course and on the ability of the control system to detect and correct unauthorized deviations. Obviously, navigation system accuracy determines the capability of aircraft to maintain assigned position and course, and efforts to reduce separation minima must be considered relative to the navigation system accuracy achievable. Similarly, efforts to reduce minima must consider the relationship between the separation minima and the ability of the surveillance system to recognize deviations from assigned position and course, identify corrective maneuvers, and communicate corrective actions to aircraft in a timely manner. Hence, such items as surveillance data resolution, ATC decision making and response time, communication delay and conflict avoidance features, as well as navigation system accuracy, are relevant to separation minima reductions.

A consensus of the Aviation Review Committee regarding the relationships between separation minima and the system functional requirements necessary to support those minima are presented in Table 4-1 (ref. 1,2). Table 4-1 addresses the NAT OTS separation minima of 60 nmi laterally/15 min longitudinally/and 2000 ft vertically (60 nmi/ 15 min/2000 ft), which are planned to be established in October 1980; the longitudinal minimum is planned to be changed to 10 min by 1982. Table 4-1 also addresses lateral minima of 60-30 nmi composite, 30 nmi and less-than-30 nmi; longitudinal minima of 5 min and less-than-5 min; and a 1000 ft vertical minimum.

For the purposes of this analysis, the less-than-30 nmi lateral minimum and the less-than-5 min longitudinal minimum alternative assumed to include the 15 nmi lateral and 2 min longitudinal minima (as discussed by the Aviation Review Committee and as considered by Working Group B of the Committee).

4.3 Potential Improvements Applications

The data entries in Table 4-1 describe the communication, navigation, surveillance, and airborne separation assurance device improvement requirements associated with each indicated separation minimum. The single sideband (SSB) HF voice communication requirement is shown capable of supporting 60 nmi and 60-30 nmi composite lateral, 15 min and 10 min longitudinal, and 1000 ft vertical separation minima; SSB in association with airborne separation assurance and navigation improvements is shown to support a 30 nmi lateral minimum. Direct communications in conjunction with other improvements are shown necessary to support 30 nmi and smaller lateral minima, and 5 min and smaller longitudinal minima.

Direct communications would be provided by a reliable air-ground link with no significant message delay characteristic, and, for the purposes of this study, is defined to be communications between pilot and controller without the intervention and services of a radio operator (communicator) intermediary, such as might be provided by HF data link, satellite data link and/or voice link, or VHF data link and/or voice link where coverage is available.

The accuracy of navigation systems meeting MNPS are assumed to be adequate to support 60 nmi (and 60-30 nmi composite lateral separations in one option) and 10 min longitudinal separation as shown in Table 4-1; the performance specification (PS) shown for the longitudinal minimum is assumed to be compatible with MNPS.

However, Table 4-1 indicates uncertainty in the system requirements necessary to support a 60-30 nmi composite separation. Composite lateral/vertical separation has been effectively used in the CEP and the NAT for a number of years, and is a possible alternative method for again improving the operations in the NAT. The use of this alternative with the present NAT lateral separation minimum is contingent upon the assurance that the composite risk would not be excessive. This is difficult since little information is available on the character and frequency of errors in the vertical dimension. This lack of data has been covered previously by assumptions on the probability of vertical overlap. With the implementation of a 60-30 nmi composite structure, the lateral overlap component could be effected by normal navigation errors (greater than 15 nmi) that occur in the system (while satisfying the MNPS) rather than by only the larger blunder type errors. The assumptions regarding vertical overlap are significantly more important in this case, thus creating reduced confidence in estimates of composite risk.

The direct resolution of this matter is to obtain performance data on the height sensing and height keeping systems. If the vertical performance is found adequate to maintain a low level of overall collision risk, the 60-30 nmi composite separation can be justified; if, however, the performance is sufficient to support a reduction to 1000 feet above FL 290, the 60-30 nmi composite alternative becomes unnecessary and undesirable. Another way 60-30 nmi composite separation might be justified would be by improvements of lateral performance, including reduced incidence of large deviations, and subsequent amendment of the MNPS criteria. Hence, MNPS (Improved or I) is introduced in Table 4-1 with allowance for implementation in combination with improved vertical navigation performance or separately (ref. 2).

The introduction of an airborne separation assurance device might also support the implementation of a 60-30 nmi structure but the objective of introducing an airborne separation assurance device also might be to effect a reduction of lateral separation minima to 30 nmi. This would be a more cost efficient improvement (from the fuel saving standpoint), partially because it is applicable to the whole oceanic area (meeting the prescribed performance requirements) and not just to the OTS and possibly other route structures.

Further reductions to 30 nmi laterally and 5 min longitudinally, smaller values of these minima, and to 1000 ft vertically are shown in Table 4-1 to require one sigma navigation accuracies defined by: MNPS (I) and PS(I); Super MNPS and Super PS; and MNPS (Vertical or V), respectively. Super MNPS shall be referred to as MNPS (Advanced) and MNPS (V) shall be referred to as PS (V) in the remainder of this text. The PS(I) and Super PS are assumed to be compatible with the MNPS (Improved) and MNPS (Advanced), respectively.

MNPS is a requirement relating to the overall system navigation performance necessary to establish a 60 nmi lateral separation minimum (ref. 3). This requirement includes a one standard deviation (referred to as one sigma) of lateral track error of less than 6.3 nmi, and considerations for the maximum proportion of flight time that aircraft might be 30 nmi or more from the cleared track, and at or between 50 nmi and 70 nmi from the cleared track. All navigation errors, including blunder errors (i.e., errors not attributable to the onboard navigation system, such as waypoint insertion or other pilot associated errors), must be included in the determination of whether MNPS is being satisfied. The MNPS (Improved), MNPS (Advanced) and PS (Vertical) indicated in Table 4-1 were judged by the Aviation Review Committee to be improvements necessary to support minima reductions, but the Committee did not quantitatively define accuracies for each. The accuracies associated with these performance improvements affect the operation of other functions, such as dependent surveillance and the airborne separation assurance device. Informal discussions held by the FAA addressed the question of defining the one sigma values and concluded that reasonable preliminary estimates of about 3 nmi one sigma and 1.5 nmi one sigma on-board navigation system accuracies might be appropriate to be associated with MNPS (Improved) and MNPS (Advanced), respectively. It was considered that the accuracy associated with MNPS (Improved) might eventually be met with the current generation of navigation system technology, and the accuracy associated with MNPS (Advanced) might be met with newer generation systems, such as laser gyros in INS and NAVSTAR/GPS. MNPS (Vertical) one sigma accuracy was not estimated, but it is expected to be addressed within a vertical separation standards and measurements program now under consideration by the United States.

Note that the one sigma accuracy values presented in the preceding paragraph are provided only for general guidance, and that rigid and explicit one sigma accuracy values for MNPS (Improved) and MNPS (Advanced) were not agreed upon. In fact, MNPS (Improved) one sigma values are expected to vary depending on application. That is, the MNPS (Improved) one sigma value associated with a 60-30 composite separation may well be different from that associated with a 30 nmi lateral separation minimum. In regard to the 30 nmi minimum, the Aviation Review Committee has considered MNPS (Improved) one sigma accuracies of 3 nmi and a slightly larger value of 3.65 nmi, subsequent to the initial estimates described in preceding paragraph (ref. 2).

The Aviation Review Committee's consensus indicates that there are alternative means for achieving the 30 nmi and smaller lateral minima and 5 min and smaller longitudinal minima. Table 4-1 shows that the 30 nmi lateral minimum might be accomplished with the aid of dependent surveillance (i.e., automatic dependent surveillance) in conjunction with direct pilot-to-controller communications and MNPS (Improved), or with the aid of an airborne separation assurance device (in lieu of automatic dependent surveillance) in conjunction with single sideband (SSB) HF voice and MNPS (Improved). Further, Table 4-1 shows that in order to achieve a 5 min longitudinal separation minimum, MNPS (Improved) and direct communications along with either automatic dependent surveillance or a separation assurance device might be required. Also, an airborne separation assurance device might be perceived to be required in conjunction with automatic dependent surveillance to support the 30 nmi lateral and 5 min longitudinal minima (ref. 2).

Table 4-1 shows that the 15 nmi lateral and 2 min longitudinal minima might be accomplished with the aid of independent surveillance (i.e., cooperative independent surveillance) in conjunction with direct pilot-to-controller communications and MNPS (Advanced). The Aviation Review Committee determined that the 15 nmi lateral and 2 min longitudinal minima would not be supported by automatic dependent surveillance (in lieu of cooperative independent surveillance) with a separation assurance device in conjunction with direct pilot-to-controller communications and MNPS (Advanced). However, the Committee did not explicitly rule out the use of automatic dependent surveillance with an airborne separation device to support less-than-30 nmi lateral and less-than-5 min longitudinal minima, but did not consider the possible extent below the 30 nmi and 5 min minima to which this alternative might be applied (ref. 2).

Automatic dependent and cooperative independent surveillance involve ATC automation and direct pilot-to-controller communication and, hence, are correlated with the communication requirements. In addition, cooperative independent surveillance involves the ability of ATS units to determine aircraft horizontal position independently of onboard position determination.

The surveillance and airborne separation assurance device improvements are associated with MNPS (Improved) and MNPS (Advanced) requirements. Available data such as those collected as part of the current MNPS program do not define navigation errors well enough to draw absolute conclusions regarding the relationships between "large" navigation errors (i.e., errors that are very infrequent and in the tails of the navigation performance distribution curve) and the exact application of the surveillance and airborne separation assurance device functions. There are indications, however, that large navigation errors are primarily due to errors other than those due to onboard navigation system accuracy (ref. 4,5). The potential improvements development described herein assumes this to be the case. The application of the communication, surveillance

and airborne separation assurance functions are never assumed to be a substitute for adequate navigation system performance, but are intended primarily to prevent potential conflicts due to large navigation errors.

4.4 Potential Improvements Design Requirements

While Table 4-1 describes the general system requirements for supporting reduced separation minima, more detailed requirements information is needed to guide the development of system design concepts. Such items as surveillance polling rates, potential conflict intervention and avoidance rates, and communication link message budgets need to be examined. In the following paragraphs, various key design parameters are addressed for the automatic dependent surveillance, cooperative independent surveillance, and airborne separation assurance device potential improvements. In the following analyses, the 30 nmi and 5 min, and the 15 nmi and 2 min lateral and longitudinal minima are assumed to be pairwise correlated because similar technical requirements are shown to be necessary to achieve each minima pair (see Table 4-1). These assumptions are supported by the observation that the 2 min longitudinal minimum is roughly comparable in distance (in en route cruise conditions) to the 15 nmi lateral minimum, and the 5 min longitudinal and 30 nmi lateral minima are similarly comparable.

4.4.1 Automatic Dependent Surveillance

Technical requirements for an automatic dependent surveillance operation have been developed using a simple model first presented in reference 6 and later reformulated. The model derives surveillance polling rates assuming that onboard navigation data can be automatically transmitted to ATC facilities. This would permit controllers to monitor flights more closely and to detect and correct deviations from assigned position and course due to navigation errors.

The model is described in Appendix C. Salient features of the model are:

- The type of error that is to be corrected is defined.
- The events, times, and geometry of the correction process are described.
- The scenario for transmitting data to the ground from individual aircraft is defined.
- The oceanic traffic projected for the year 2005 is analyzed to obtain an estimate of the situations that would require dependent surveillance and the amount of communications that would be required to support that surveillance as a function of separation minima.

The last point was necessary because the model assumed that aircraft operating at or near legal separation minima must be monitored more closely than other aircraft. Hence, the concept of "proximate aircraft" (i.e., those aircraft within a specified distance of each other) was introduced. In the model, a polling or surveillance interrogation update rate of 5 minutes was assumed for all nonproximate aircraft.

The model was used to examine the consequences of specific polling rates for proximate aircraft. Polling rates for proximate aircraft of up to 2 polls per minute per aircraft were considered for the 30 nmi/5 min case, although a one-minute position update rate might be adequate (see Appendix C, Section C.2). To provide a conservative guideline for the design of the network HF and satellite data link and voice systems described in Section 5, data rates were based upon the higher position update rate of 2 per minute for proximate aircraft (see Appendix C, Section C.3). Note that the simple network HF data link and voice system described in Section 5 is designed assuming an average position update interval of 5 minutes for all aircraft.

4.4.2 Cooperative Independent Surveillance

The only currently practical system improvement capable of providing independent surveillance in the NAT is a multiple satellite communications system. Link budgets and other requirements for the satellite data link and voice system are adequate to support a cooperative independent surveillance function (e.g., see ref. 7 and 8). The same polling rates considered for the dependent surveillance function in the preceding paragraph apply. Such a system could have a better position determination accuracy (e.g., 1 nmi) than the assumed dependent surveillance cases. The primary differences between the dependent and independent surveillance satellite-based systems involve the positions and number of satellites used and the type of hardware that must be used to process signals.

4.5 Airborne Separation Assurance Device

Table 4-1 presents an airborne separation assurance device as a potential requirement that might, by itself or as a supplement to other potential improvements, permit a reduction in lateral and longitudinal separation minima. The utilization of an airborne separation assurance device to achieve a reduction of minima would require acceptance by the aviation community of the projected frequency of potential collision avoidance maneuvers.

Analysis of the behavior of collision avoidance devices is made difficult because their characteristics can be tailored to their environment. Navigation error characteristics and traffic flow all affect the expected number of collision maneuvers that might occur using an airborne separation assurance device for collision avoidance. Estimates of the number of potential collision avoidance maneuvers that might occur have

been made, based on current traffic flows in the NAT, for several alternative lateral separation minima and assumed distributions of navigation errors. Details of the calculations are presented in Appendix C.

Figure 4-2 shows estimates of collision avoidance maneuver frequencies that might occur subject to the assumptions detailed in Appendix C. The number of alarms expected to occur in the entire system and the reciprocal (mean time between alarms) is plotted as a function of lateral separation minimum. Three cases are plotted, corresponding to several different assumptions regarding the size and type of navigation errors. In all cases, the errors were assumed, for computational convenience, to have a probability distribution function suggested by references 9 and 10 and discussed in Appendix C.

Each set of parameters corresponds to a particular set of assumptions about NAT navigation error. For example, the first and second cases plotted in Figure 4-2 correspond to the assumptions that errors exactly meet the criterion (the so called "zeta" and "eta"). In the first case the errors were assumed to rigorously minimize the "eta" criterion (the criterion that the proportion of total flight time spent by aircraft 30 nmi or more off track shall be less than 0.00053). In the second case, the NAT/SPG "zeta" and "eta" parameters specified for the NAT were used. In the third case in the Figure, navigation errors which appear more representative of errors being measured in the NAT were used to derive a set of parameters for analysis. (Note that errors observed in the NAT must be less than those used in the first two cases to permit the application of 60 nmi separations.)

Note, from Figure 4-2, that alarms for 30 nmi separations with current system traffic flow could occur at the rate of between one per year and one every week or so, depending on navigation error assumptions used. Similarly, at 15 nmi lateral minimum, the frequency range for separation alarms varies between one-fifth per day and two per day. The conclusion drawn is that the alarm rate is quite sensitive to the error characteristics, of which sufficient data for more detailed analysis are not available.

4.6 References

1. Committee to Review the Application of Satellite and Other Techniques to Civil Aviation, "Report of the 4th Meeting of the Committee, 27-29 May 1980, Williamsburg, Virginia" (December 1980).

2. Committee to Review the Application of Satellite and Other Techniques to Civil Aviation, "Report of the 5th Meeting of the Committee, 8-17 December, 1980, Torremolinos/Malaga, Spain" (March 1980).

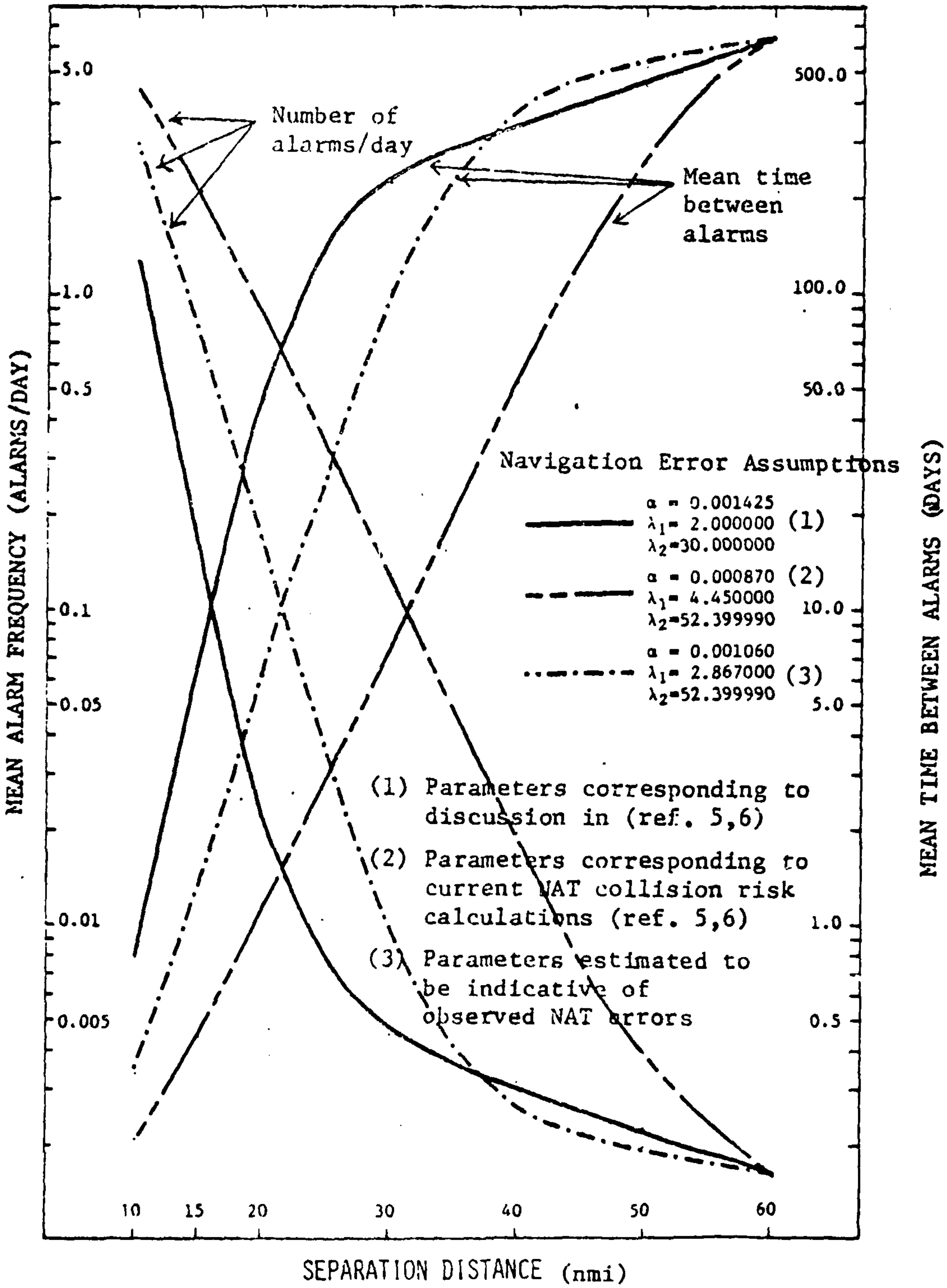


Figure 4-2 ESTIMATES OF ALARM-RATES WITH
AN AIRBORNE SEPARATION ASSURANCE DEVICE CAPABILITY

3. International Civil Aviation Organization, "Regional Supplementary Procedures," Doc 7030/2, Second Edition (1971 with amendments through August 1978).

4. North Atlantic Systems Planning Group, "Summary of Discussions and Conclusions of the Seventeenth Meeting of the NAT Systems Planning Group," Draft Report (March 1980).

5. Correspondence from G. A. Cook, National Air Traffic Services, Ref. No. 8BB/C7/21/4, September 23, 1980, with enclosure by Mr.Victor Attwoll.

6. Conrad,B. et al., "Preliminary Estimates of Communications Requirements," SRI International (July 1980).

7. Boeing, "Experimental L-Band Satellite Communications/ Surveillance Terminal Study," Vol. I-V, Document No. D6-60105 (November 1968).

8. The Boeing Commercial Aircraft Company," Air Traffic Control Experimentation and Evaluation with the NASA ATS-6 Satellite," FAA Report No. FAA-RD-75-173 (September 1976).

9. "Analytical Development of a Minimum Navigation Performance Specification, Appendix A to the Report on Agenda Item 1.2: Report of the Limited North Atlantic Regional Air Navigation Meeting 1976," ICAO Doc. 9182, LIM NAT, pg 1.2-13 to 1.2-24 (1976).

10. "Description of a Model for Assessing the Collision Risk in Parallel ATS Route Structures: Methodology for the Deviation of Separation Minima Applied to the Spacing Between Parallel Tracks in ATS Route Structures," ICAO Circular 120-An/89/2, Second Ed., pg 8-19 (1976).

5.0 NAT POTENTIAL IMPROVEMENTS AND COSTS

5.1 Introduction

Many potential oceanic improvements depend on specific subsystems to perform enhanced functions in the NAT. This section briefly describes those subsystems and estimates costs associated with implementation and operation of network HF and satellite data link and voice communication systems, separation assurance devices, altimetry, and satellite-based surveillance systems. These estimated subsystem design characteristics, capabilities, and costs are included for comparison and for evaluating the usefulness of major system design changes. If one or more subsystems appear to offer specific cost benefits, it is assumed that a refinement of the system design would be considered in detail by appropriate authorities.

5.2 Network HF Data Link and Voice

5.2.1 System Overview

Working Group B of the Aviation Review Committee has postulated an HF data link and voice system description to meet the polling requirements defined in Section 4 (see ref. 1). This system is designed to minimize the effects of ionospheric vagaries by providing diverse frequencies and spacial paths for propagation. The spacial diversity is an automated version of the networking procedure; the frequency diversity uses "families" of frequencies, with a continual automated procedure to sound out which of a candidate set of frequencies offers good propagation characteristics at any given time. Appendix A contains a synopsis of the Working Group B description of this network data-link concept along with additional references and a summary description of a simple network HF data link concept.

The potential coverage pattern of an HF system is shown in Figure 5-1. The HF system is depicted schematically in Figure 5-2. The system has the following characteristics:

(1) HF ground stations (e.g., stations currently in existence in the NAT) are tied closely together by commercial (e.g., satellite) links.

(2) Two ground stations (one European, one North American) can act as master controllers for the entire system. Only one would function as a master controller at a time.

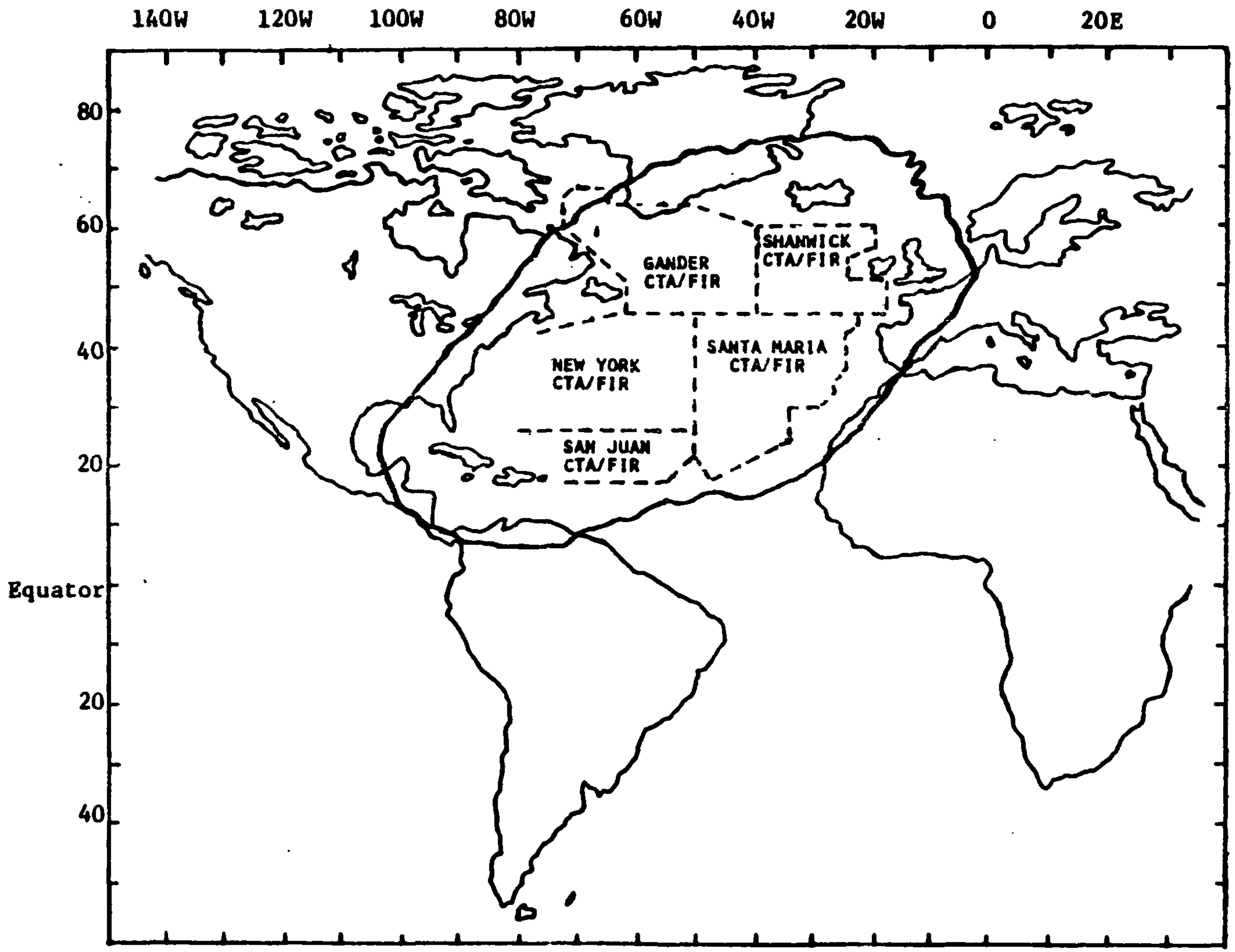
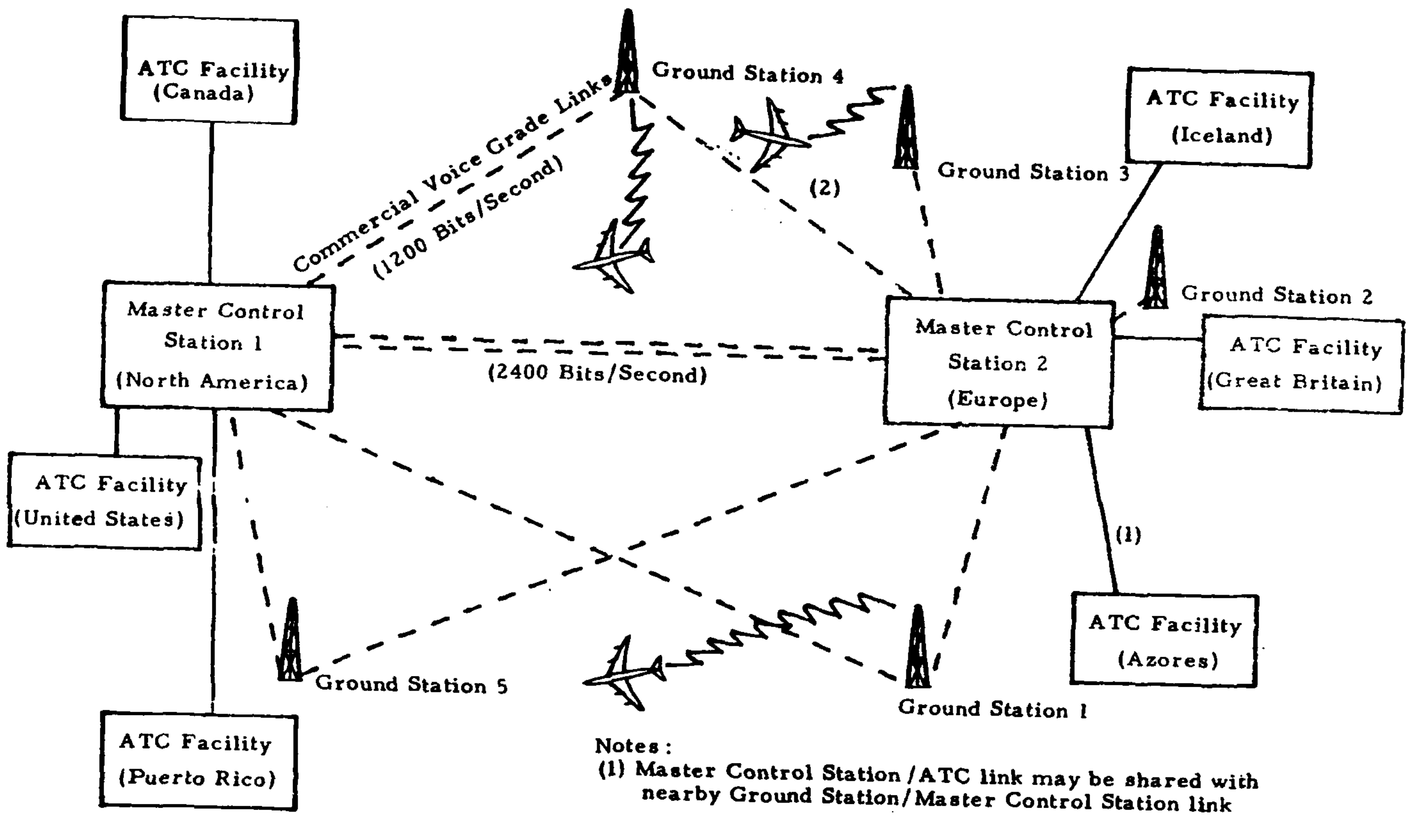


Figure 5-1

POTENTIAL COVERAGE OF THE NETWORK
HF DATA LINK AND VOICE SYSTEM



Notes:

(1) Master Control Station/ATC link may be shared with nearby Ground Station/Master Control Station link

(2) Dotted lines represent data links. Voice would be carried on existing ATC circuits and telephone connections.

Figure 5-2

NETWORK HF DATA LINK AND VOICE SYSTEM CONFIGURATION

(3) Each ground station would be assigned a set of frequencies (e.g., a family of up to eight frequencies spanning the HF band) and a set of aircraft to interrogate using its transmitters. This set of frequencies can be altered as required by the master station

(4) Each ground station would poll designated aircraft on all frequencies in its families simultaneously. Polling rates could be as frequent as once every 30 seconds (possible alternatives could be once every 1 minute or every 2 minutes; the system concept design is based on once every 30 seconds) for aircraft flying near each other or approaching each other and five minutes for other aircraft.

(5) Aircraft would be assigned a family of frequencies, as well as polling and reply slots. Aircraft receivers would cycle through the range of frequencies and determine a frequency that would be good to use for replying to a poll. Approximately every 10 seconds, an aircraft could evaluate an alternative frequency, based on the quality of reception of the polling signal.

(6) Ground stations would have receivers for all frequencies allowing continual monitoring of propagation as a function of spacial position relative to stations. Families of frequencies could be reassigned to different stations, or aircraft frequency family changes could be made when necessary (e.g., several times/day).

Since every HF ground station must be able to exchange information with the master stations, lines capable of 1200 bit/ second data transfer that interconnect facilities would be necessary for the high-speed (30-second) polling interval (half of this capacity would be used for control, half for information flow).

The HF system offers the possibility of using equipment already contained in existing aircraft avionics installations and ground stations to accomplish desired communications. Only a limited number of new elements would need to be added to the existing system. The HF propagation medium is not sufficiently well modeled to permit detailed a priori estimates of the reliability or predictability of the HF system. Further, spectrum availability for the system based on current International Telecommunication Union (ITU) regulations may not be completely adequate to support the system.

5.2.2 Airborne Component

Avionics required for this system are indicated in Figure 5-3. Estimating the cost and capabilities of the avionics requires that several major areas of concern--all related to timing problems--be considered. In particular, it is important to determine how often the transmit frequency actually would be changed by the system, the length assigned to a receive cycle in which a system must evaluate a new frequency, and the length of transmitted message types.

These timing problems affect costs. The reliability of aircraft antenna couplers (both existing and projected new technology devices) is based on tuning occurrence rates; moreover, transceivers currently in use have inherent time delays due to automatic gain control (AGC) circuitry and other components that affect the time required to process a signal. However, it appears possible to configure a system so that the transceivers in use on the bulk of the existing fleet can support an HF data system, using currently installed HF couplers and Collins 628T or newer HF transceivers (618T or older transceivers are not assumed adequate for this application).

Avionics costs are not assumed sensitive to the data rates considered in Section 4. Because they are highly sensitive to assumptions about the usability of specific equipment, the cost of several alternatives was developed (see Table 5-1). If all new couplers or if major transceiver design changes were needed, per unit costs for existing aircraft could increase by some $40,000 or so. Complete design and testing of prototype avionic installations would be required to determine the utility of current avionics to a new HF system.

5.2.3 Ground Stations

Two types of ground stations are required to operate the HF system: (1) master control stations, with sufficient computer capacity and communications to coordinate the system, and (2) air/ground communication stations that operate to provide path diversity (see Figure 5-2).

A survey of the current ground stations (ref. 2) has shown that existing facilities have some of the receiving and transmitting equipment required to implement an HF data system. Antenna configuration and siting remains to be evaluated in the context of a specific system design.

For cost estimation purposes, it was assumed that two of the existing ground stations currently meet propagation requirements. Further, it was assumed that two ground stations would require complete relocation and one would require partial relocation. The ground stations are depicted schematically in Figure 5-4. No existing stations were specifically identified as candidates for replacement or enhancement. The Azores represents a particularly good site for propagation of HF signals to NAT traffic.

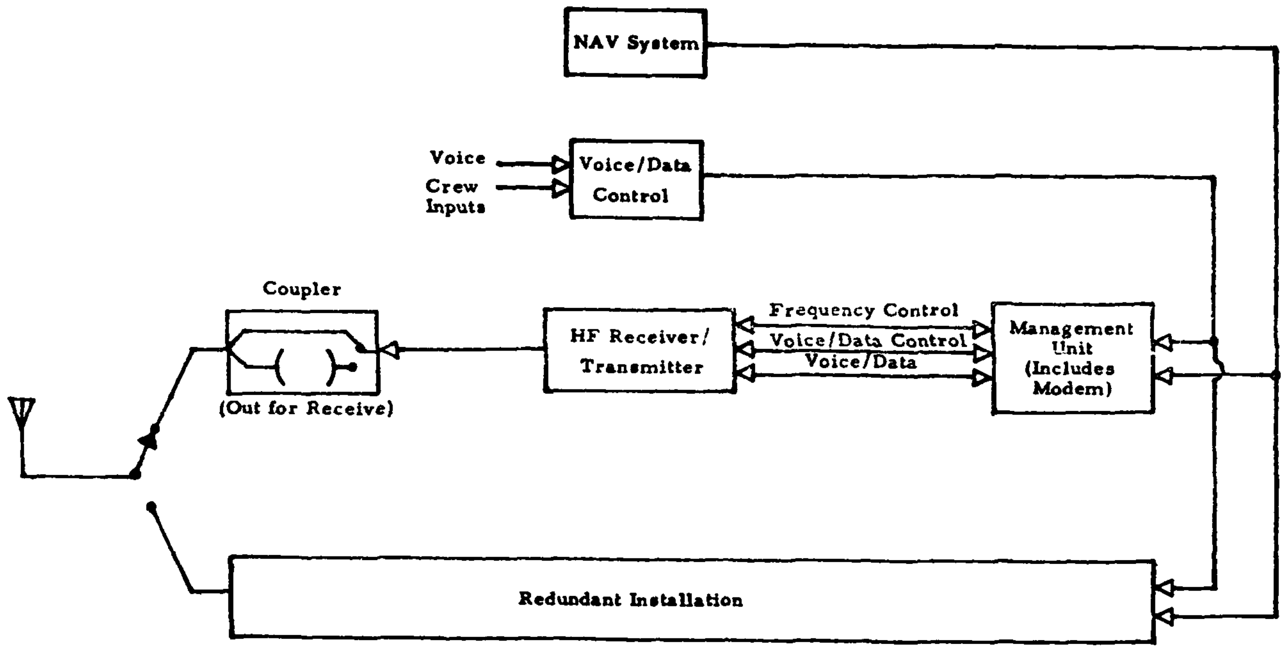


Figure 5-3

NETWORK HF DATA LINK AND VOICE SYSTEM AIRBORNE COMPONENTS

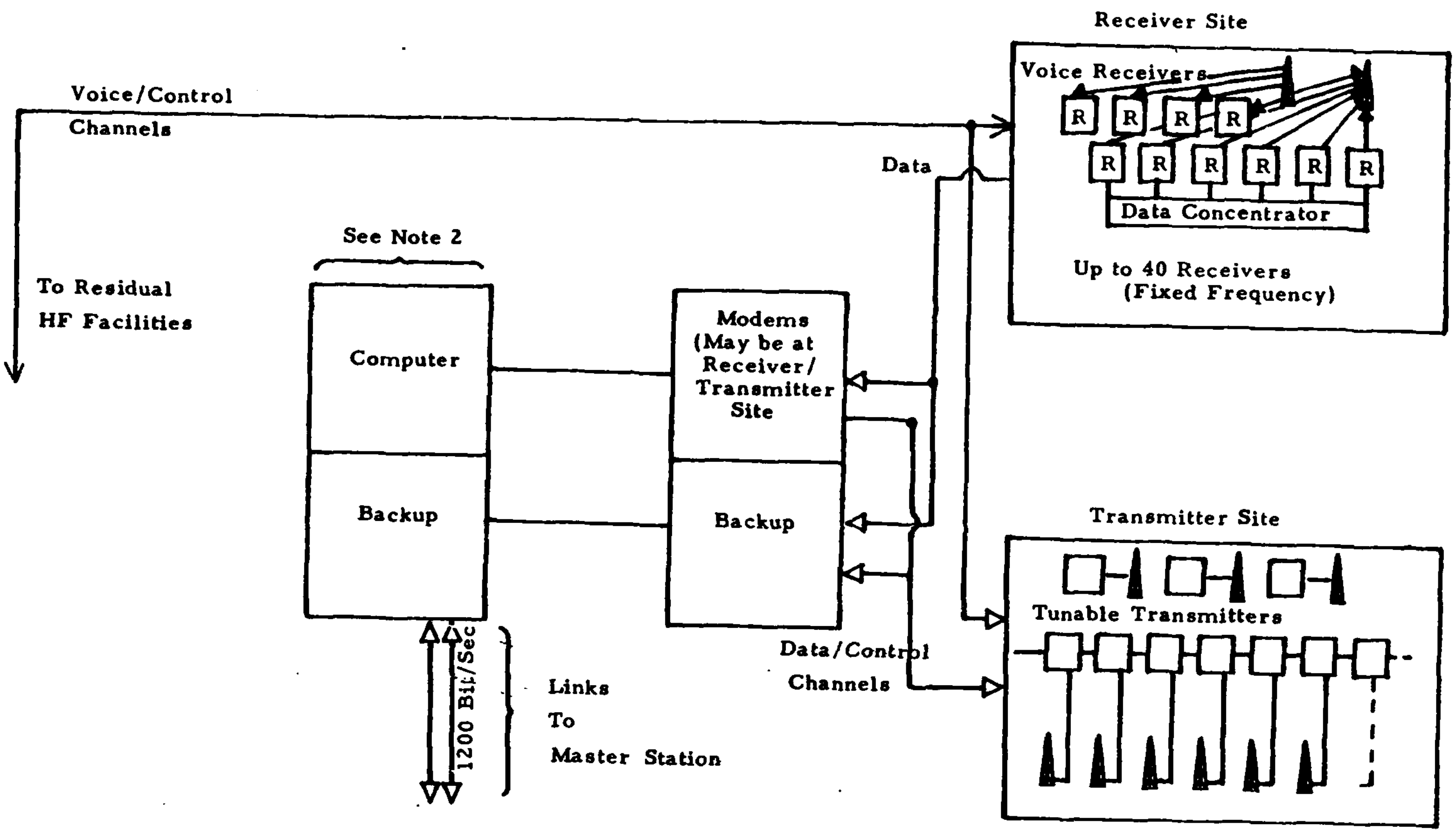


Figure 5-4

NETWORK HF DATA LINK AND VOICE SYSTEM
AIR/GROUND COMMUNICATION STATION

Table 5-1

NETWORK HF DATA LINK AND VOICE
AVIONICS SUBSYSTEM COSTS FOR DUAL UNITS
(Thousands of 1979 US Dollars)

Component	Aircraft(5) with 628T R/T	Aircraft with 618 or older R/T	New Aircraft
Management unit (two)	37(3)	37(3)	37(3)
Voice/data control and display units	3	3	3
R/Ts (two)	---	20	20 (2)
Couplers antenna	---	----(1)	20 (2)
Installations	3(4)	3(4)	3(4)
Total	43	63	83

Notes

(1) If faster tuning (e.g. relay type) antenna couplers are required, it is expected that these will cost approximately $20,000 U.S. (1979) for each installation and all aircraft would be required to have them.

(2) These elements would be required even if no system improvements were postulated.

(3) These costs include $20,000 for two very sophisticated modems and coders, chosen as strawmen based on an average of very low and very high conceivable costs.

(4) Installation costs were estimated to be triple those estimated by a US carrier for an ACARS installation.

(5) This column of costs represents expected incremental costs for installing a data system. Other columns are for reference purposes only.

Available bandwidth may pose a problem for these ground stations. Having each station assigned a single family of frequencies for constant use until propagation conditions require reassignment is desirable. Stations can time share families of frequencies by transmitting station identification along with polling requests. Currently, six frequencies are available in the 3,6, and 8 MHz bands, three in the 11 MHz band and two in the 13 MHz band for the NAT . It might be possible to use the E-CAR frequencies in each of the 3,5,6,9,11, and 18 MHz also. If only the 23 NAT frequencies are used, it would not be possible to avoid continually time sharing frequencies. It would be desirable to have seven or more frequencies distributed in the 3 to 17 MHz range for each station plus five more frequencies for a total of approximately 40 frequencies.

Total ground station costs are presented in Table 5-2.

5.2.4 Summary of Network HF Data Links and Voice System

The costs for instituting an HF communication system are based on implementation of such a system by the year 1988. It is assumed that a 3-year design refinement phase, including propagation studies and generation of specifications achievable between 1981 and 1983, will be carried out. It is assumed that the HF ground network portion of the system is constructed between 1984 and 1987 with testing and shakedown during 1987 and 1988.

Table 5-3 estimates yearly costs to providers for building and maintaining a ground station support network. Costs are derived as follows: A $3,000,000 feasibility program involving propagation studies, testing of equipment, and derivation of detailed specifications for all signal formats and timings is developed over a 3-year period (1981-1983). System engineering is estimated to be $1,000,000 for 1983, when feasibility studies are being completed. The total ground station cost of $11,981,000 presented in Table 5-2 is distributed over the 1984-1987 period. Testing of ground stations is estimated to be $500,000 for the year 1987. Yearly maintenance costs are based on a staff of ten technicians at an average cost of $40,000 per person year. Cost of data links to coordinate network communications is based on ten duplex links between facilities at $10,000 per month per link. These links could effectively offload AFTN data from other links.

User avionics costs are a function of fleet size, which currently totals 1,059 aircraft (ref. 3). Operators using the NAT are expected to equip their long-range aircraft so that maximum operating flexibility is achieved. Linear growth in the number of these aircraft between 1985 and 2005 is assumed. The projected total by 2005 is 1,959 aircraft, a growth rate of about 85% in accordance with the projected number of NAT flights (ref. 4). Figure 5-5 shows the assumed fleet size as a function of time.

Table 5-2

NETWORK HF DATA LINK AND VOICE
GROUND STATION COMPONENT COSTS FOR THE NAT
(Thousands of 1979 US Dollars)

Component	Number	Unit Cost	Total Cost	Comment
1-kw HF transmitter dollars	15	25	375	equipment cost range 21 to 34k
Transmitter multicouplers	15	5	75	
New transmitters antennas	15	4	60	e.g., ten vertical LPs, ten conical monopoles (TCI 503)
Receivers estimated	150	4	600	unit costs as by UK and Canada
Receiver antennas	15	15	225	e.g., TCI 612
Receiver multicouplers	15	5	75	
Coaxial Cable	40,000	.002	80	
Microwave R/T(2)	10	30	300	
Miscellaneous test equipment	10	50	500	For each site
Primary power	5	100	500	
Land Preparation and installation for new antennas at existing and/or new sites experience	68(antennas)	14.5	986	Includes antenna installation costs based on Canadian
Land (2.5 sites with 30 acres/site)	75 acres	5	375	
Small processors/data concentration	12	40	480	
Large processors	4	250	1000	
Software	10,000 lines	.1	1000	
Terminals with CRT/printer, keyboard	40	10	400	
Modulators	90	5	450	
Demodulators	200	10	2,000	
Building (for 2.5 sites)	15,000 ft	.1	1500	
System Engineering	2.5	400	1000	
Total Fixed Costs			11981(1)	

(1) Fixed costs do not include preliminary feasibility and system design costs estimated at $4,000,000.

(2) These are links between nearby receiver, transmit, and control sites. Satellite link rentals of 10 international channels at an annual cost of 1,200,000 dollars also are anticipated. These links will carry AFTN traffic also.

Table 5-3

NETWORK HF DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING THE GROUND
STATION NETWORK FOR THE NAT
(1979 US Dollars)

Year	Development and Ground Station Capital Costs		Equipment Maintenance Costs	Ten Interconnection Links
1981	1,000,000	(feasibility study)	--	
1982	1,000,000	(feasibility study)	--	
1983	2,000,000	(feasibility and engineering)	--	
1984	2,995,000	(ground station installation)(1)	--	
1985	2,995,000	(ground station installation)	200,000	
1986	2,995,000	(ground station installation)	300,000	
1987	3,495,000	(ground station installation and 500,000 demonstration program)	400,000	1,200,000
1988			400,000	1,200,000
1989			400,000	1,200,000
1990			400,000	1,200,000
1991			400,000	1,200,000
1992			400,000	1,200,000
1993			400,000	1,200,000
1994			400,000	1,200,000
1995			400,000	1,200,000
1996			400,000	1,200,000
1997			400,000	1,200,000
1998			400,000	1,200,000
1999			400,000	1,200,000
2000			400,000	1,200,000
2001			400,000	1,200,000
2002			400,000	1,200,000
2003			400,000	1,200,000
2004			400,000	1,200,000
2005			400,000	1,200,000
Total	16,480,000			

(1) Costs of Table 5-2 expended over 4 years.

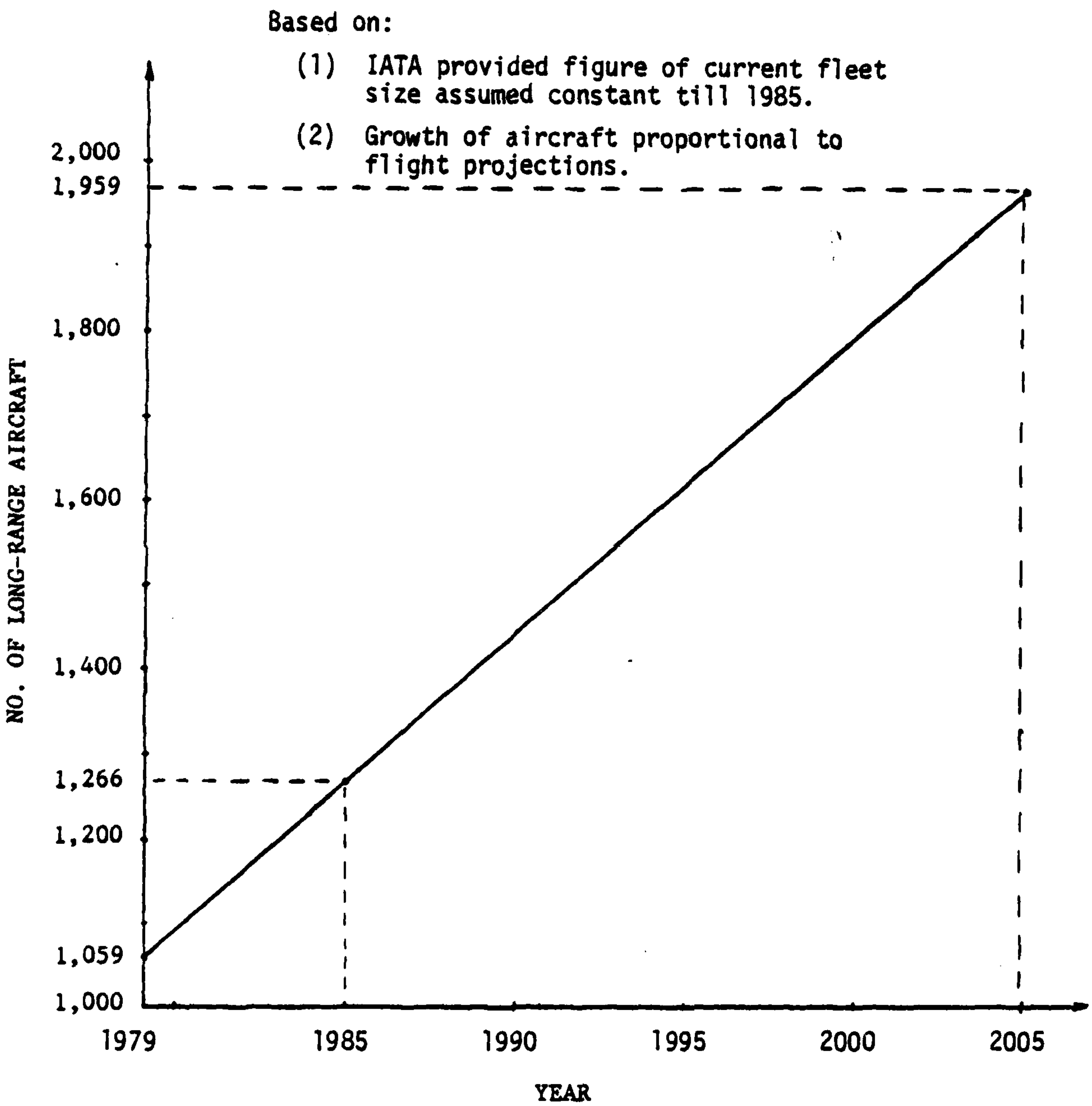


FIGURE 5-5 NUMBER OF LONG-RANGE AIRCRAFT OWNED BY OPERATORS USING THE NAT

Table 5-4 shows user cost by year. It has been assumed that in the period 1985-1987 existing aircraft with 628T or newer HF transceivers are equipped with the components specified in the first column of Table 5-1. In these and subsequent years, all new aircraft require the additional equipment. The cost of the additional equipment is estimated to be the same as that of the retrofits because new aircraft would require HF equipment whether or not new systems were installed.

The estimated annual user operating costs shown in Table 5-4 are obtained from the avionics maintenance cost estimates presented in Table 5-5, which are cost approximations based on a $1 per hour maintenance expense. The user avionics maintenance costs are small in comparison with other system operating and component costs, and variations to the user maintenance cost estimates will not significantly impact system cost comparisons.

5.3 Satellite Data Link and Voice

The major advantages of a satellite system are its ability to provide the required grade of service over a large geographic area, its expandability (given allotted aviation bandwidth) to fulfill all anticipated aviation communication capacity and coverage requirements, and its potential to perform other functions such as independent surveillance. The primary disadvantages of satellite communications are potentially high capital costs and possible institutional problems associated with funding, developing, and operating a satellite system. The costs of a satellite data link and voice system are a function of costs for the ground station, satellite, and avionics. Considerable research and development in the satellite area has been conducted in the past 20 years (e.g., ref. 5 and 6). The resulting available information on systems and costs was put together specifically for the several satellite system concepts defined by Working Group B of the Review Committee (ref. 7), including a data and voice and a voice-only system. Appendix B contains a synopsis of the Working Group B description and references for additional supporting technical data.

In this section, the satellite data link and voice system design is described, and the costs for this design and a data link-only design (both based on L-band) are estimated.

5.3.1 System Overview

The satellite-based air-ground communications network is designed with adequate capacity to meet communication requirements defined in Section 4.1. The coverage of such a system from a single satellite would roughly encompass the area shown in Figure 5-6. Such a satellite system is not expected to preclude the need for aircraft to carry HF SSB avionics in the future, since HF will be needed for other areas of the world. Its major impact on HF would be to reduce the scale (and possibly number) of existing HF ground stations to a size typified by the two-operator San Juan ARINC facility (ref. 2).

Table 5-4

NETWORK HF DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT
(1979 US Dollars)

Year	Avionics Cost(1)	New Aircraft Cost(2)	Total	Yearly User Cost ($1/operating hour)
1985	18,146,000	1,488,660	19,634,660	1,112,000
1986	18,146,000	1,488,660	19,634,660	1,138,000
1987	18,146,000	1,488,660	19,634,660	1,165,000
1988		1,488,660	1,488,660	1,193,000
1989		1,488,660	1,488,660	1,221,000
1990		1,488,660	1,488,660	1,250,000
1991		1,488,660	1,488,660	1,279,000
1992		1,488,660	1,488,660	1,309,000
1993		1,488,660	1,488,660	1,340,000
1994		1,488,660	1,488,660	1,372,000
1995		1,488,660	1,488,660	1,404,000
1996		1,488,660	1,488,660	1,437,000
1997		1,488,660	1,488,660	1,470,000
1998		1,488,660	1,488,660	1,503,000
1999		1,488,660	1,488,660	1,538,000
2000		1,488,660	1,488,660	1,573,000
2001		1,488,660	1,488,660	1,610,000
2002		1,488,660	1,488,660	1,647,000
2003		1,488,660	1,488,660	1,684,000
2004		1,488,660	1,488,660	1,723,000
2005		1,488,660	1,488,660	1,763,000
Totals	54,438,000	31,261,860	85,699,860	

(1) Retrofit 422 aircraft per year for 3 years at $43,000/aircraft.

(2) Added HF costs only for 34.62 aircraft/year.

Table 5-5

ESTIMATED USER AVIONICS ANNUAL OPERATING (MAINTENANCE) COST

Year	Annual Cost (1979 $US Thousands)
1979	951
1980	977
1981	1001
1982	1030
1983	1058
1984	1087
1985	1112
1986	1138
1987	1165
1988	1193
1989	1221
1990	1250
1991	1279
1992	1309
1993	1340
1994	1372
1995	1404
1996	1437
1997	1470
1998	1503
1999	1538
2000	1573
2001	1610
2002	1647
2003	1684
2004	1723
2005	1763

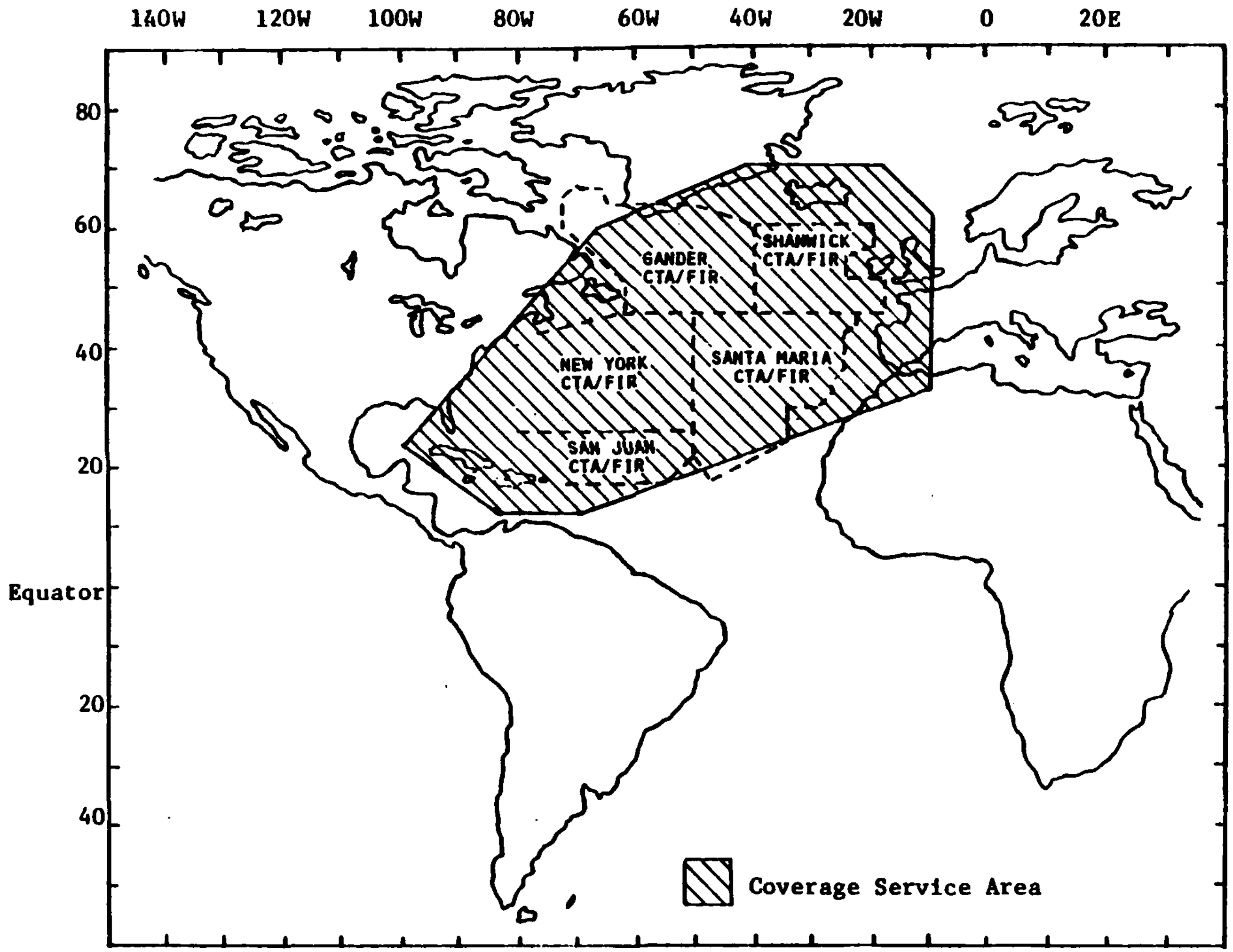


Figure 5-6

SATELLITE DATA LINK AND VOICE SYSTEM,
ESTIMATED AREA OF COVERAGE ACHIEVABLE WITH L-BAND SATELLITE

An overall representation of the satellite system is shown in Figure 5-7. A baseline system using L-band frequencies for aircraft/satellite links has been assumed, but variations in the configuration were also considered (e.g., using VHF instead of L-band for the aircraft/satellite link). In Figure 5-7, it is assumed that two identical facilities will control polling of aircraft to provide institutional redundancy. Other ground stations can receive uplink and downlink information via C-band links.

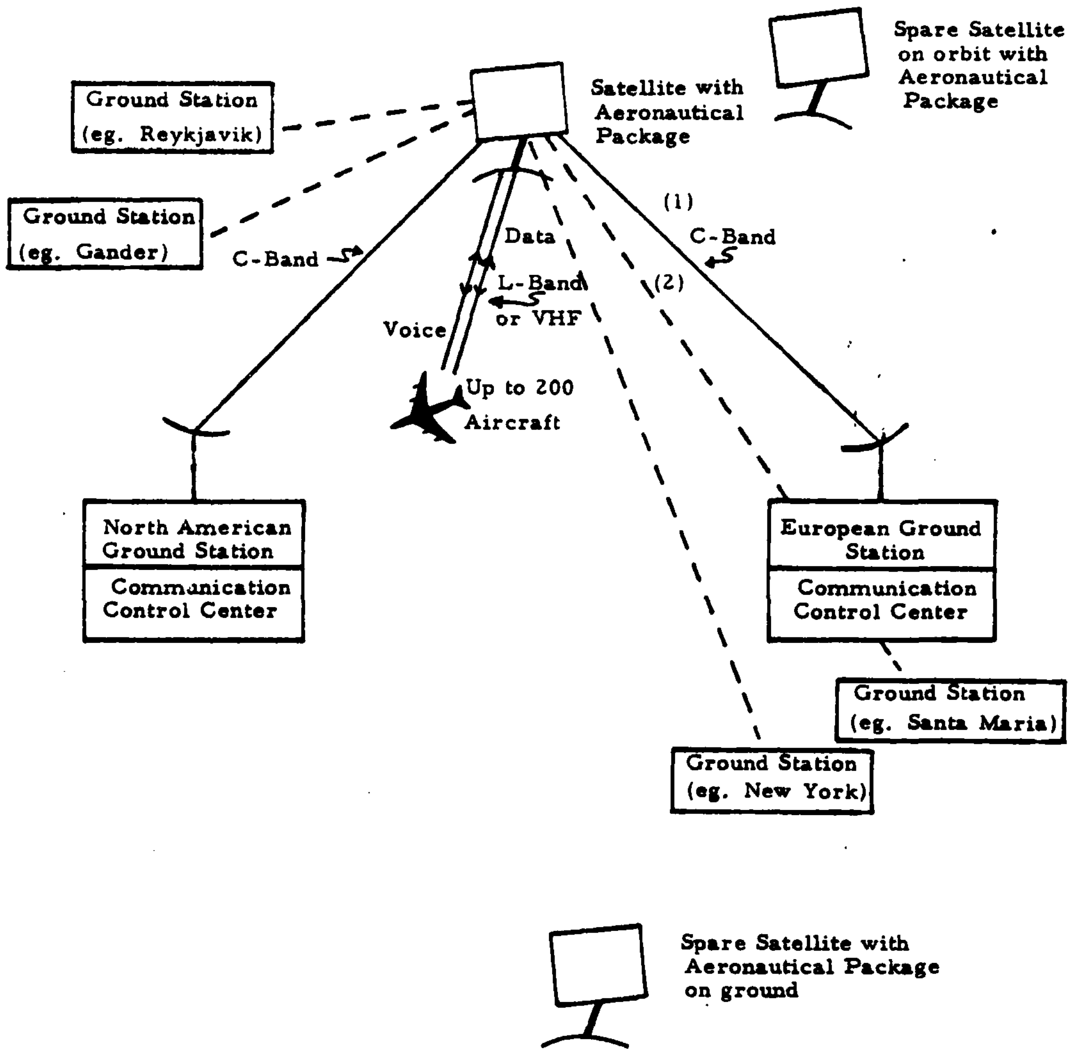
To control polling, the communication control centers (CCCs) must have extensive knowledge of aircraft position and intentions. The two CCCs must coordinate their control efforts so switchover between them is possible at any time. In addition, any aviation facility that processes aircraft into or out of oceanic FIRs must be able to communicate with the CCCs. Much of this information flow is analogous to flow now being sent over the AFTN. The C-band channels are used to provide the point-to-point supportive data flows and would displace the need for some of that AFTN flow.

The overall system is conceptually simple. Every aircraft in the entire coverage area would have a unique identificaton code. Relevant frequencies are defined in reference 8. Aircraft data would be requested sequentially using a single L-band channel in the 1545-1559 MHz band. A reply would be issued in the 1646.5 to 1660.5 MHz band using one or more channels. The aviation C-band frequencies of 5000 to 5250 MHz or a commercial band would be used to carry data between the satellite and ground stations. One voice channel for occasional use would be included in the system. Voice communications would also be carried on a residual HF communication system.

The use of VHF instead of L-band is possible on the aircraft/satellite links. However, there is more technical uncertainty associated with the performance of VHF, in terms of multipath signal characteristics, aircraft antenna discrimination of multipath, impact of scintillation fades, and possible ground generated interference. In addition, aircraft antenna size, installation, and costs are more of a concern for VHF.

The cost of the satellite/aircraft data channels is not strongly influenced by the differences among the data flow requirement alternatives considered. The highest data rates of 200 bits/second from ground to air and 700 bits/second for air to ground are considered for the design of the satellite system (see the data rate requirements developed in Section C.3 of Appendix C and summarized in table C-9). The 700 bits/ second might be contained in one channel or several subchannels.

The requirement for even a single voice channel via satellite has a considerable impact on satellite system costs due to the need for higher continuous power levels in the avionics and in the spacecraft. Hence, technical and cost information has been specified for systems with and



(1) C-Band links may be special links provided for aeronautical service or commercial links

(2)— — — Indicate these lines may be provided by mechanisms other than the satellite

Figure 5-7

SATELLITE DATA LINK AND VOICE SYSTEM CONFIGURATION

without voice. Channel design philosophy can significantly affect costs if a data only (no voice) system is considered. The voice channel has been designed for low utilization (i.e., no more than 0.2 channel utilization factor) to provide ready access.

5.3.2 Space Segment

The in-orbit payload represents a major cost factor in the implementation of a satellite system. If a satellite is vital to the ATC function, both a primary and a backup satellite payload must be in orbit (in separate satellites) and a completed payload must exist on the ground.

On the basis of the detailed satellite information presented in Appendix B and ref. 7, the required payload for a satellite to provide data link only or data and a single voice channel would be much smaller than the payload for which satellites and launchers are typically designed. A data only system proportion of a payload (including transponders, power supplies, structure, attitude control, etc.) would weigh about 69 kg, while a data and voice channel proportion of a payload would weigh about 115 kg. This would be a small proportion of a typical payload of some 500 kg.

Three alternative assumptions have been considered regarding estimation of space package costs. These are (1) an ideal cost sharing arrangement, based on finding an available spacecraft whose weight, power, size, orbital position, etc., would all complement those of the aviation space segment package needs, and whose owners would be willing to cost share accordingly, (2) a less than ideal sharing arrangement in which the aviation community might have to share perhaps half the cost of a spacecraft, or (3) the launch of a small satellite dedicated to aeronautical use only. This last option is not currently judged to be cost effective since many spacecraft components such as the structure and control system cannot be linearly scaled with payload size. Hence, both launch and development costs make this option unattractive. The first assumption was used for estimating the cost of a basic system. Costs of the second and third options can be inferred from sensitivity analysis discussed in subsequent sections (see Appendix H).

Assembling a satellite package does not pose serious technical problems. However, the size of the antennas, the duty cycle of a voice channel, the channeling of data to coordinate ground status, and other factors would affect the convenience with which an aviation package could be shared with other packages and hence the cost. In particular, VHF antennas would be larger than L-band.

The actual costs of implementing and operating the in-orbit communication elements include development and production of satellites (or portions thereof), pro-rated launch of the satellites and of satellite station keeping and telemetry. Satellite capability on the ground or in

the orbit must be sufficient to assure reliability. For costing purposes two in-orbit satellites were assumed to provide adequate redundancy.

Satellite costs can vary considerably with the institutional mechanism used to provide the space segment capability. Costs can also vary with the availability of compatible spacecraft partners for sharing vehicle subsystems. Table 5-6 shows two cost estimates, both of which were obtained assuming near optimum payload sharing (i.e., no excess capacity purchased.) One set was based on the assumption that historical cost figures could be interpolated as a function of size and power (ref. 9, 10). The second set of estimates shown in the table was obtained from the European Space Agency (ref. 11), subsequent to discussions on satellites (ref. 12). Further cost discussions are contained in ref. 7 and Appendix H.

5.3.3 Ground Components

Ground components can have a variety of configurations. Figure 5-8 highlights ground station configurations for master stations. Many physical aspects of the stations can vary depending on institutional and economic considerations. For example, radio equipment and antenna dishes might be owned, leased, or shared using commercial ground stations.

Ground station hardware is well developed, and all necessary hardware can be procured from vendors. However, development is necessary to integrate ground components, to create software to control and channel input/output displays, and to design procedures for routing data and control between facilities.

In Table 5-7 earth terminal costs are itemized. It is assumed that one active master control station is in charge of communications at all times. It is also assumed that this active master can use the C-band links to send to interested ATC facilities all pertinent actual and planned flight information, and all operating parameters required for the backup master control station to take over polling functions. It is further assumed that data required to conduct polling, such as aircraft identification and planned routes, can be entered into the master control station via C-band links from other ATC facilities. Total data flow to the satellite from the active master would require a 2400 bit/second uplink. Data from remote facilities to the master station could be handled at a lower rate.

5.3.4 Aircraft Components

To operate within the satellite-based communication system postulated here, aircraft would have to carry a new class of avionics, consisting of radio-related equipment operating at VHF or L-band, and input and control equipment consisting of a processor to concentrate

Table 5-6

SATELLITE DATA LINK AND VOICE
ESTIMATED MINIMUM SPACECRAFT-RELATED COSTS FOR AN
L-BAND SATELLITE COMMUNICATION SYSTEM
(Millions of 1979 US Dollars)

Cost Item	All Data	Voice and Data	Expenditure Time
Development cost for payload & interface	min 3.7(1) max 5.25(2)	min 6.2(1) max 8.0(2)	Initial cost (one time)
Recurring costs (payloads)	1.4(1)	2.3(1) 3.3(2)	Every seven years
Launch costs (shuttle)	1.6(1) 2.3(2)	2.6(1) 3.7(2)	Every seven years
Tracking, telemetry and command (TTC)	.25	.25	Yearly

(1) Cost obtained by a historical comparison of weight and power requirements with other systems (ref. 9, 10).

(2) Cost obtained from ESA.

Table 5-7

SATELLITE DATA LINK AND VOICE
ESTIMATED GROUND COMPONENT COSTS
FOR TWO SATELLITE EARTH STATIONS FOR THE NAT
(Thousands of 1979 US Dollars)

Cost Component	Number	Unit Cost	Amount	Comment
4.5-meter Dishes	4	4.0	16	3-meter also possible
Up/down converters	8	8	64	
Modems	8	8	64	
Preamps	8	1.2	9.6	
Power amplifiers	8	20.0	160	
Large-scale processors	4	250	1000	Common processors for both stations
Tested and debugged computer software $100/line	10k lines	.1	1000	Common to both stations
Terminals with CRT and printers	40	10	400	As per Appendix B description
System installation, integration; building and space for computer, radio gear	2	100	200	
Building space	400 sq. meters	1.0	400	
Remote earth stations	4	150	600	For distribution of A/G data input of data to polling algorithms
Total			3913.6	
Total system maintenance			400	Yearly charge

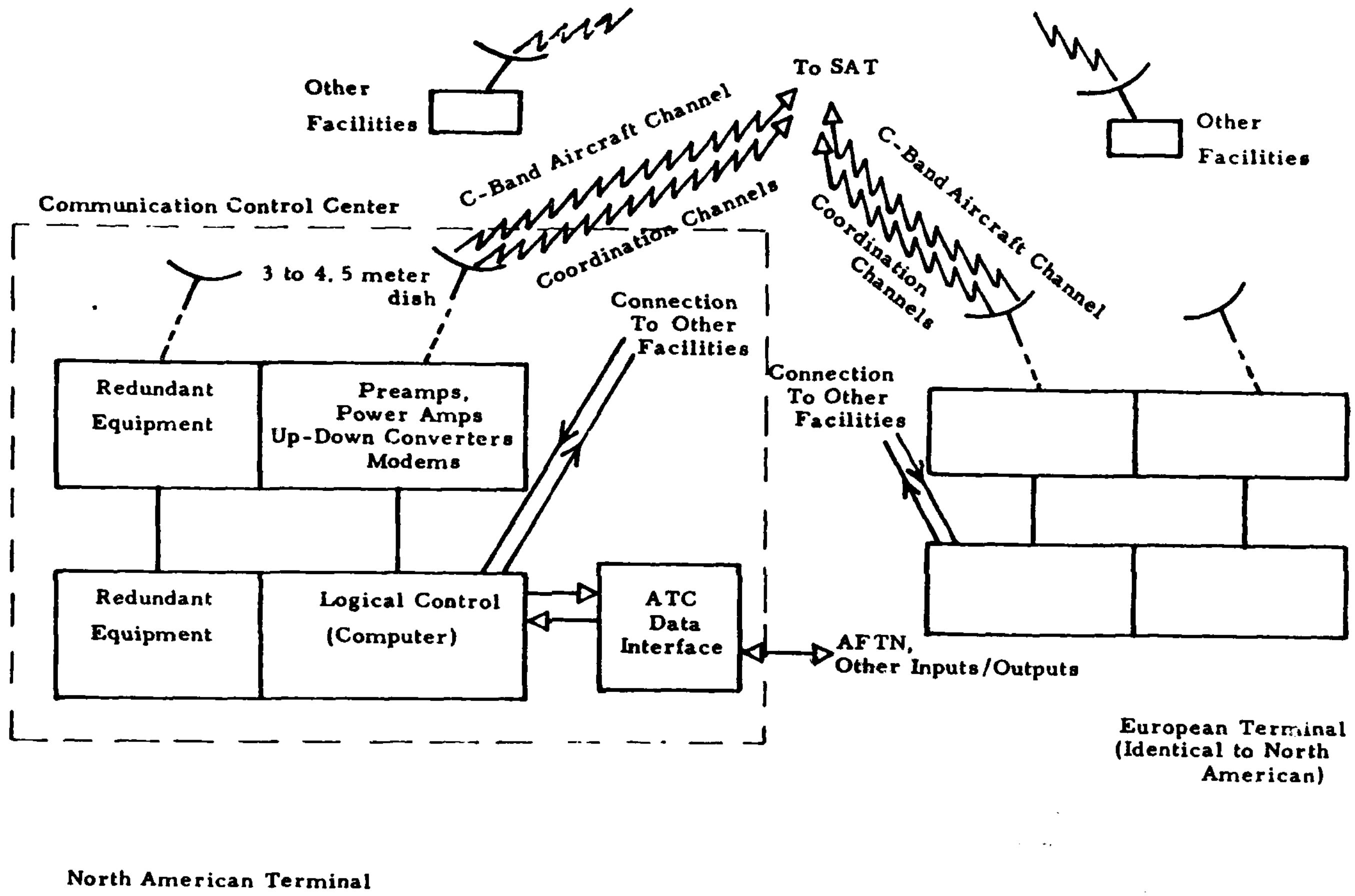
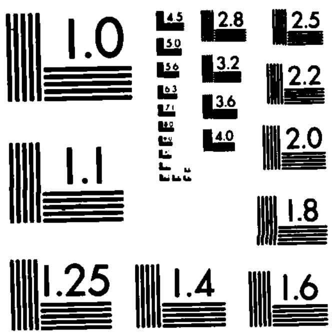


Figure 5-8

SATELLITE DATA LINK AND VOICE SYSTEM
GROUND SEGMENT

AD-A123 896 OCEANIC AREA SYSTEM IMPROVEMENT STUDY (OASIS) VOLUME I 2/5
EXECUTIVE SUMMARY A..(U) SRI INTERNATIONAL MENLO PARK
CA G J COULURIS ET AL. SEP 81 OASIS FAA-EM-81-17-1
UNCLASSIFIED DOT-FA79WA-4265 F/G 17/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

data from various on board equipment. Typical input would be pilot keyboard entry, ARINC specification 429-3 data busses (ref. 13) from miscellaneous equipment, flight management computer system data as per ARINC characteristic 702-1 (ref. 14), and the inertial reference system as per ARINC characteristic 704-1 (ref. 15. The processor would buffer aircraft data, demodulate and decode ground signals, and select and modulate airborne data for transmittal to the ground. Figure 5-9 illustrates the required equipment.

Several technical issues affect implementation of the radio frequency portion of the avionics; these concern: (1) antenna gains reasonably achievable; (2) multipath and scintillation problems; and (3) cost or technical problems inherent in building L-band power amplifiers. Since significant costs are associated with mounting the amplifiers far from the antenna, a baseline system cost was estimated with an amplifier located near the antenna.

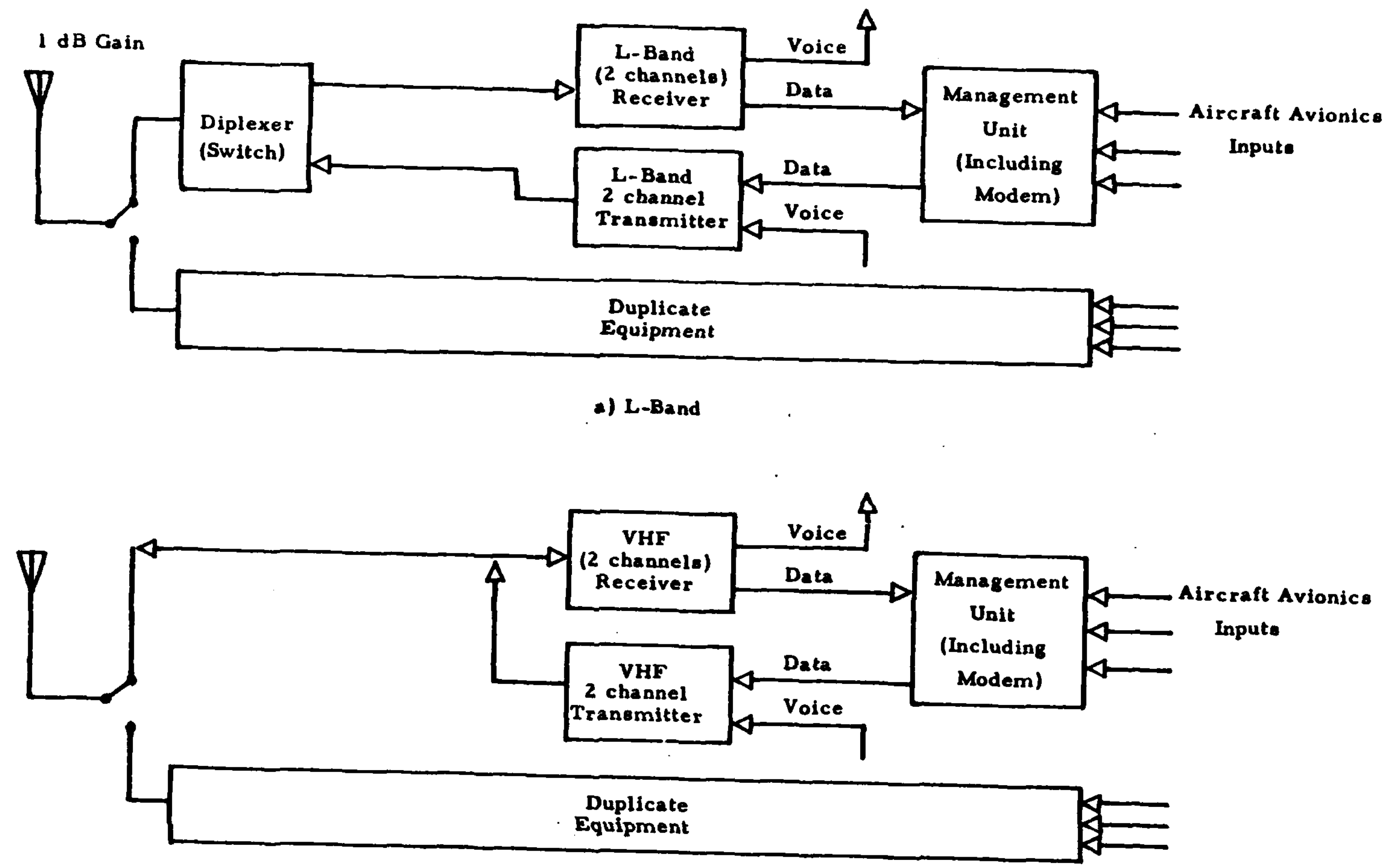
The costs of both L-band and VHF avionics were estimated by an avionics manufacturer. The manufacturer's VHF estimates, however, did not include the cost of an antenna, whereas the L-band cost estimates did. VHF antenna costs are based on general estimates from an airframe manufacturer. Estimated costs are shown in Table 5-8. Note that VHF costs are lower.

The costs estimated per unit are not expected to vary significantly with the number of units involved. The number of dual system installations produced would vary from 1,000 for the existing fleet up to 2,000 for the anticipated fleet.

Cost of installation of equipment is based on mounting antenna and cables during major overhauls, since removal of interior furnishing and metal work will be required.

5.3.5 Summary of Satellite Systems

Yearly costs associated with satellite systems have been calculated under the several assumptions discussed in Appendix B. Costs are summarized in Table 5-9A. It is assumed that a 2-year $1,500,000 per year effort will be required to generate specifications, including antenna and noise tests. Development of a satellite payload is estimated to take place between 1983 and 1985, at a cost of $7,600,000. Costs for satellite and launches are taken as an average of cost estimates shown in Table 5-6. Ground stations are assumed to be developed over 4 years with their costs as shown in Table 5-7 spread evenly over those years. Maintenance costs are identical to those shown in Table 5-3. An initial launch is assumed to take place in 1986 to provide a space segment for component verification. A spare is assumed to be built at the same time. Another launch is projected for 1988. The two satellites and ground stations would then be ready for general validation of system performance. Table 5.9B shows the parallel costs for a system with only data link communications.



b) VHF

Figure 5-9

SATELLITE DATA LINK AND VOICE SYSTEM
AIRBORNE SEGMENT

Table 5-8

SATELLITE DATA LINK AND VOICE
AVIONICS SUBSYSTEM COSTS FOR DUAL UNITS
(Thousands of 1979 US Dollars)

Component	L-Band(1) 30 sec polling With voice	L-Band(1) 30 sec polling No voice	VHF(2) 30 sec polling With voice
RF equipment	2 x 16 = 32	2 x 8 = 16	2 x 4.5 = 9
Central units	2 x 8.5 = 17	2 x 8.5 = 17	2 x 8.5 = 17
Antenna	.5	.5	3.0
Antenna installation (3)	1.2	1.2	2.0
Control unit and RF installation	.6	.6	.6
Total	51.3	35.3	31.6

Other costs

Structural analysis and certification for each aircraft type: 50.

Maintenance on any system: .001/flight hour.

(1) L-Band assumes power amplifier mounted near antenna to minimize required RF power; 1 min poll has no significanc cost decrease

(2) Not considered sensitive to poll rate or voice requirement

(3) Assumes no stringer or bulk head cutting costs

Table 5-9A

SATELLITE DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE NAT
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1980				
1981	1,500,000 (develop, test, spec.)			
1982	1,500,000 (develop, test, spec.)			
1983	2,533,333			
1984	2,533,333			
1985	2,533,333	978,400		
1986	8,700,000 (2 satellits including ground spare, 1 launch)	978,400	100,000	
1987		978,400	200,000	
1988	5,700,000 (1 sat, 1 launch)	978,400	400,000	250,000
1989			400,000	250,000
1990			400,000	250,000
1991			400,000	250,000
1992			400,000	250,000
1993	5,700,000 (1 sat, 1 launch)		400,000	250,000
1994			400,000	250,000
1995	5,700,000 (1 sat, 1 launch)		400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998			400,000	250,000
1999			400,000	250,000
2000	5,700,000 (1 sat, 1 launch)		400,000	250,000
2001			400,000	250,000
2002	5,700,000 (1 sat, 1 launch)		400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

Table 5-9B

SATELLITE DATA LINK (WITHOUT VOICE)
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR NAT
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1980				
1981	1,500,000 (develop, test, spec.)			
1982	1,500,000 (develop, test, spec.)			
1983	1,490,000			
1984	1,490,000			
1985	1,490,000	978,400		
1986	4,750,000 (2 sats, 1 launch)	978,400	100,000	
1987		978,400	200,000	
1988	3,350,000 (1 sat, 1 launch)	978,400	400,000	250,000
1989			400,000	250,000
1990			400,000	250,000
1991			400,000	250,000
1992			400,000	250,000
1995	3,350,000 (1 sat, 1 launch)		400,000	250,000
1994			400,000	250,000
1995	3,350,000 (1 sat, 1 launch)		400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998			400,000	250,000
1999			400,000	250,000
2000	3,350,000 (1 sat, 1 launch)		400,000	250,000
2001			400,000	250,000
2002	3,350,000 (1 sat, 1 launch)		400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

User avionics costs are a function of fleet size and fleet use. These were discussed in Section 5.2.4 and are estimated to be identical to those presented in that section based on comparable cost estimates.

Avionics costs involve retrofit of the existing fleet with transceivers, antennas, and other components between 1985 and 1987 at a cost of $51,300 per aircraft. This cost assumes retrofit during major overhauls. New aircraft would be equipped as they come on line at the rate of 34.62 aircraft per year at a slightly lower cost of $50,000 per unit. Table 5-10A shows these costs. Yearly avionics operating costs assume about $1 per aircraft hour of oceanic use. Table 5-10B shows similar costs for a data link only system.

5.4 Airborne Separation Assurance Device

5.4.1 Overview

Self-contained separation assurance devices offer a potential method of operating in oceanic airspace with reduced separation minima and increased operating flexibility. Prototypes have been under development (ref. 17-20). Such devices might be mandated in some airspace within this decade.

5.4.2 Separation Assurance Device (Airborne) Costs

The costs attributable to implementing and using a separation assurance device are those allocated to equipping and operating aircraft with such devices. For cost comparison purposes, the device costs might be totally or partially allocated to providing service in the oceanic areas, and allocations of 100 and 50% of total costs have been assumed. Testing of separation assurance devices is likely to be accomplished in a domestic environment, but analysis and demonstration of performance in an oceanic environment may be needed. A cost of $1,000,000 is assumed to cover these items.

For convenience, per unit costs are based on the BCAS, which was developed by the FAA to be compatible with separation assurance provided by existing radar systems and the discrete address beacon system (DABS). DABS avionics are an integral part of the BCAS system (for air-air coordination and communication), and thus the associated avionics are being designed as a single unit. Table 5-11 presents sample costs (ref. 20), which assume that aircraft would carry redundant systems for reliability. For cost estimation purposes, it is assumed that the entire oceanic fleet requires only omnidirectional antennas.

Tables 5-12 and 5-13A and 5-13B present the costs by year of an airborne separation assurance device implementation based on a 100% allocation of user capital equipment costs to oceanic operations. These costs are used in the analysis presented in subsequent sections. Fleet size and utilization have been described in Section 5.2.4. In addition,

Table 5-10A
SATELLITE DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT
(1979 US Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost(3)
1985	21,648,600	1,731,000	23,379,600	1,112,000
1986	21,648,600	1,731,000	23,379,600	1,138,000
1987	21,648,600	1,731,000	23,379,600	1,165,000
1988	0	1,731,000	1,731,000	1,193,000
1989	0	1,731,000	1,731,000	1,221,000
1990	0	1,731,000	1,731,000	1,250,000
1991	0	1,731,000	1,731,000	1,279,000
1992	0	1,731,000	1,731,000	1,309,000
1993	0	1,731,000	1,731,000	1,340,000
1994	0	1,731,000	1,731,000	1,372,000
1995	0	1,731,000	1,731,000	1,404,000
1996	0	1,731,000	1,731,000	1,437,000
1997	0	1,731,000	1,731,000	1,470,000
1998	0	1,731,000	1,731,000	1,503,000
1999	0	1,731,000	1,731,000	1,538,000
2000	0	1,731,000	1,731,000	1,573,000
2001	0	1,731,000	1,731,000	1,610,000
2002	0	1,731,000	1,731,000	1,647,000
2003	0	1,731,000	1,731,000	1,684,000
2004	0	1,731,000	1,731,000	1,723,000
2005	0	1,731,000	1,731,000	1,763,000
Total	64,945,800	36,351,000	101,296,800	

(1) 422 aircraft/year at $51,300 per aircraft for 3 years.

(2) 34.62 new aircraft per year at $50,000 per aircraft.
Equipment depreciation over 20 years.

(3) Costs calculations based on $1/operating hour.

Table 5-10B

SATELLITE DATA LINK (WITHOUT VOICE)
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR NAT
(1979 US Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost (3)
1985	14,896,600	1,177,080	16,073,680	1,112,000
1986	14,896,600	1,177,080	16,073,680	1,138,000
1987	14,896,600	1,177,080	16,073,680	1,165,000
1988	0	1,177,080	1,177,080	1,193,000
1989	0	1,177,080	1,177,080	1,221,000
1990	0	1,177,080	1,177,080	1,250,000
1991	0	1,177,080	1,177,080	1,279,000
1992	0	1,177,080	1,177,080	1,309,000
1993	0	1,177,080	1,177,080	1,340,000
1994	0	1,177,080	1,177,080	1,372,000
1995	0	1,177,080	1,177,080	1,404,000
1996	0	1,177,080	1,177,080	1,437,000
1997	0	1,177,080	1,177,080	1,470,000
1998	0	1,177,080	1,177,080	1,503,000
1999	0	1,177,080	1,177,080	1,538,000
2000	0	1,177,080	1,177,080	1,573,000
2001	0	1,177,080	1,177,080	1,610,000
2002	0	1,177,080	1,177,080	1,647,000
2003	0	1,177,080	1,177,080	1,684,000
2004	0	1,177,080	1,177,080	1,723,000
2005	0	1,177,080	1,177,080	1,763,000
Total	44,689,800	24,718,680	69,408,480	

(1) 422 aircraft/year at $35,300 per aircraft for 3 years.

(2) 34.62 new aircraft per year at $34,000 per aircraft.

(3) Maintenance costs: $1 per use hour

Table 5-11

AIRBORNE SEPARATION ASSURANCE DEVICE
AVIONICS SUBSYSTEM COSTS FOR DUAL UNITS
(Thousands of 1979 US Dollars)

	BCAS Avionics (2)	Installation
System with omni antenna only (1)	2 x 23 = 46	5.6 (retrofit) 2.8 (new)
System with angle of arrival antenna (display proximate aircraft positions)	2 x 27.5 = 55	8.0

(1) System will use existing lower beacon antenna and an additional antenna would be added to the top of the aircraft.

(2) System includes the cost of the integrated BCAS/DABS avionics (used as a model for costing).

Table 5-12

AIRBORNE SEPARATION ASSURANCE DEVICE
PROVIDER COSTS FOR OCEANIC AREA DEMONSTRATION FOR THE NAT;
BEGIN IMPLEMENTATION IN 1990 (1)
(1979 US Dollars)

Year	Expenditure
1982	500,000
1983	500,000

(1) Note that the oceanic environment is considerably simpler than terminal or high density airspace.

Delay expenditures by 5 years to 1987 and 1988 for implementation in 1995.

Table 5-13A

AIRBORNE SEPARATION ASSURANCE DEVICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
100% OCEANIC COST ALLOCATION FOR NAT; BEGIN IMPLEMENTATION IN 1985
(1979 US Dollars)

Year	Retrofit Cost (1)	New Aircraft Equipment Cost (2)	Total	Yearly User Cost ($1/operating hour)
1985	21,775,200	1,689,456	23,464,656	1,112,000
1986	21,775,200	1,689,456	23,464,656	1,138,000
1987	21,775,200	1,689,456	23,464,656	1,165,000
1988		1,689,456	1,689,456	1,193,000
1989		1,689,456	1,689,456	1,221,000
1990		1,689,456	1,689,456	1,250,000
1991		1,689,456	1,689,456	1,279,000
1992		1,689,456	1,689,456	1,309,000
1993		1,689,456	1,689,456	1,340,000
1994		1,689,456	1,689,456	1,372,000
1995		1,689,456	1,689,456	1,404,000
1996		1,689,456	1,689,456	1,437,000
1997		1,689,456	1,689,456	1,470,000
1998		1,689,456	1,689,456	1,503,000
1999		1,689,456	1,689,456	1,538,000
2000		1,689,456	1,689,456	1,573,000
2001		1,689,456	1,689,456	1,610,000
2002		1,689,456	1,689,456	1,647,000
2003		1,689,456	1,689,456	1,684,000
2004		1,689,456	1,689,456	1,723,000
2005		1,689,456	1,689,456	1,763,000
Total	65,325,600	35,478,576	100,804,176	

(1) Retrofit 422 aircraft per year at $51,600 per aircraft.

(2) 34.62 aircraft at $48,800 per aircraft.

Table 5-13B

AIRBORNE SEPARATION ASSURANCE DEVICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
100% OCEANIC COST ALLOCATION FOR NAT; DELAY START OF IMPLEMENTATION UNTIL 1990
(1979 US Dollars)

Year	Retrofit Cost (1)	New Aircraft Equipment Cost (2)	Total	Yearly User Cost ($1/operating hour)
1990	24,768,000	1,689,456	26,457,456	1,250,000
1991	24,768,000	1,689,456	26,457,456	1,279,000
1992	24,768,000	1,689,456	26,457,456	1,309,000
1993		1,689,456	1,689,456	1,340,000
1994		1,689,456	1,689,456	1,372,000
1995		1,689,456	1,689,456	1,404,000
1996		1,689,456	1,689,456	1,437,000
1997		1,689,456	1,689,456	1,470,000
1998		1,689,456	1,689,456	1,503,000
1999		1,689,456	1,689,456	1,538,000
2000		1,689,456	1,689,456	1,573,000
2001		1,689,456	1,689,456	1,610,000
2002		1,689,456	1,689,456	1,647,000
2003		1,689,456	1,689,456	1,684,000
2004		1,689,456	1,689,456	1,723,000
2005		1,689,456	1,689,456	1,763,000
Total	74,304,000	27,031,296	101,335,296	

(1) Retrofit 480 aircraft per year at $51,600 per aircraft.

(2) 34.62 aircraft at $48,800 per aircraft.

the same costs with only a 50% allocation to oceanic systems is considered in later sections. Table 5-13C presents cost by year for a 50% allocation with installation in the years 1988 through 1990.

Subsequent to the aforementioned cost analysis, the BCAS system concept including DABS has been superseded by the US Traffic Alert and Collision Avoidance System (TCAS) concept. The BCAS-based cost estimates are representative of a minimum TCAS-II capability which includes one Mode S transponder with omnidirectional top and bottom antennae (the cost estimates include one additional antenna for the retrofit case), one TCAS unit with two directional antennae (for top and bottom), and installation. In the event of TCAS unit failure, the Mode S transponder could still be used, and, if both fail, an existing SSR transponder or a backup Mode S transponder could be used (but costs were not assumed for a Mode S transponder for the retrofit case).

5.5 Altimetry

5.5.1 Overview

Aircraft maintain vertical en route flight profiles by reference to barometric altimeters. Consideration currently is being given to undertake a study to assess the feasibility of using existing or improved procedures and equipment for operation with reduced minimums (e.g., ref. 22). Vertical separations of 2000 feet are used globally to provide separations between aircraft above FL 290, independent of traffic density or other factors involved in formalized mathematical calculations of collision risk causes. The frequency, magnitude, and cause of vertical errors are not sufficiently well known to determine feasibility of reduced separation with existing equipment or to establish minimum operational performance standards. Reference 22 suggests methodologies for collecting data and indicates that Japan has an ongoing effort to gather data and the Soviet Union has ongoing theoretical studies associated with vertical separation reductions.

For oceanic purposes, several conceivable situations are possible:

(1) Current systems may be proved capable of reduced vertical separations, globally or within airspace meeting MNPS type system controls and qualifications.

(2) Existing static-pressure systems might be improved via alternative installation procedures, better calibration of signals in air-data computers, and other methods for use in global or prespecified areas.

(3) Another technology such as radar altimetry, which is currently available, might be used to provide primary and/or supplementary guidance in oceanic areas (ref. 21).

Table 5-13C

AIRBORNE SEPARATION ASSURANCE DEVICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
50% OCEANIC COST ALLOCATION FOR NAT; DELAY START OF IMPLEMENTATION UNTIL 1988
(1979 US Dollars)

Year	Retrofit Cost (1)	New Aircraft Equipment Cost (2)	Total	Yearly User Cost ($1/operating hour)
1988	11,806,596	844,728	12,651,324	1,193,000
1989	11,806,596	844,728	25,302.648	1,221,000
1990	11,806,596	844,728	12,651,324	1,250,000
1991		844,728	844,728	1,279,000
1992		844,728	844,728	1,309,000
1993		844,728	844,728	1,340,000
1994		844,728	844,728	1,372,000
1995		844,728	844,728	1,404,000
1996		844,728	844,728	1,437,000
1997		844,728	844,728	1,470,000
1998		844,728	844,728	1,503,000
1999		844,728	844,728	1,538,000
2000		844,728	844,728	1,573,000
2001		844,728	844,728	1,610,000
2002		844,728	844,728	1,647,000
2003		844,728	844,728	1,684,000
2004		844,728	844,728	1,723,000
2005		844,728	844,728	1,763,000
Total	35,419,788	15,205,104	50,624,892	

(1) Retrofit 458 aircraft per year at $51,600 per aircraft.

(2) 34.62 aircraft at $48,800 per aircraft.

(4) In conjunction with (1) through (3) above, transmissions (similar to Mode C) might be made via mechanisms (such as data link) described in other sections to detect certain types of flight technical errors (e.g., ref. 23).

(5) Autopilots with specified vertical hold characteristics might be required.

(6) Altitude alerting devices to warn of diversions from assigned flight level might be required.

Reduction of vertical separation is of great interest for domestic as well as oceanic airspace. Hence, any research costs related to the use of barometric altimetry guidance may not be allocated to strictly "oceanic" improvement accounts. The cost of other devices, such as radar altimeters which are of utility primarily to oceanic users, would have to be assigned as oceanic improvement costs.

5.5.2 Sample Cost Items

Possible representative costs associated with undefined improvement items are given here to establish sensitivities of improvement cost to benefits. Such costs might come about by the use of specifically calibrated static systems coupled to autopilots, or the use of supplementary equipment (e.g., radar altimeters) to complement barometric altimetry or other improvements. However, no specific possibilities can be identified at this time. A cost of $6,000,000 is assigned to performing the research associated with analysis of existing system errors and defining methodologies to assure installation accuracy. A cost of $50 per aircraft per year is assigned to users for more comprehensive calibration of equipment (assumed 1 man hour of additional calibration per aircraft per year). A $10,000 cost per aircraft is assigned to improvements on old aircraft and a $5,000 cost is assigned to new aircraft. The fleet size of Section 5.2.4 is used for all calculations. Table 5-14 summarizes the resulting yearly costs.

5.6 Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice

5.6.1 Overview

This satellite based improvement would provide cooperative independent surveillance in addition to air/ground voice and data communications capabilities. Past studies have shown the technical feasibility of implementing satellite-based surveillance systems (ref. 5). Ground stations using various signal processing techniques can determine the position of aircraft if aircraft respond via two or more appropriately located satellites to a ground station-originated signal. The response would contain encoded altitude and other data. Aircraft antenna gains; power budgets, and other parameters are within the same ranges as have

Table 5-14

ALTIMETRY SYSTEM IMPROVEMENT
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR NAT (3)
(1979 US Dollars)

Year	Provider Costs	User Calibration and Modification Costs (1)	User New Equipment Costs (2)	User Yearly Maintenance ($50/Aircraft)
1981	1,500,000			
1982	1,500,000			
1983	1,500,000			
1984	1,500,000			
1985		4,220,000	173,100	22,831
1986		4,220,000	173,100	45,662
1987		4,220,000	173,100	68,493
1988			173,100	70,224
1989			173,100	71,955
1990			173,100	73,686
1991			173,100	75,417
1992			173,100	77,148
1993			173,100	78,879
1994			173,100	80,610
1995			173,100	82,341
1996			173,100	84,072
1997			173,100	85,803
1998			173,100	87,534
1999			173,100	89,265
2000			173,100	90,996
2001			173,100	92,727
2002			173,100	94,458
2003			173,100	96,189
2004			173,100	97,920
2005			173,100	99,657
Total	6,000,000	12,660,000	3,635,100	

(1) 422 aircraft per year at $10,000 per aircraft.

(2) 34.62 new aircraft per year at $5,000 per aircraft.

(3) Sample costs for demonstration purposes only.

been prescribed for the voice plus data link systems. Hence, costs of a surveillance system can be estimated by extrapolating those generated in Section 5.3 for a satellite voice and data system.

5.6.2 System Costs

A cooperative independent surveillance system, in contrast with the system of Section 5.3, would require at least one additional satellite in orbit, i.e., two for surveillance and one as a spare. In addition, ground stations would require equipment and software to process signals from satellites. Airborne equipment might require diplexers and other hardware to support such a system.

Table 5-15A presents the provider cost estimates for the multiple satellites data link and voice system. This table differs from Table 5-9A in the inclusion of additional cost for extra satellite packages and launches and in the assumptions that an additional $2,000,000 of ground station equipment would be required. Table 5-15B considers the cost of a delayed satellite surveillance option discussed in subsequent sections. Table 5-16A estimates user costs. That table is derived in the same manner as Table 5-10 with the exception that an additional cost of $5,000 per aircraft avionics system has been added to handle precise timing and a higher quality diplexer cost. Table 5-16B shows the cost of a delayed implementation corresponding to Table 5-15B. Tables 5-15B and 5-16B reflect implementation associated with operation of cooperative independent surveillance starting in 1995.

5.7 Simple Network HF Data Link and Voice System Alternatives

5.7.1 System Overview

Working Group B developed a very sophisticated HF system described in Section 5.2 to provide the best possible chance for HF to meet performance requirements associated with reductions of separation minima (see Appendix A and ref. 24). To gauge the extent to which NAT operating costs might be reduced with a less complex network HF data link system, a simplified system was designed by Working Group B. The simple network HF data link and voice system is designed to be less expensive than the network HF data link and voice system, and is designed to operate within the existing HF frequency allocations with a growth potential for evolution to more sophisticated sounding and related operations.

Costs for providing the simplified HF data link capability without the sophisticated frequency and spacial diversity inherent in the network HF data link and voice system proposed in Section 5.2 are estimated in this section. Two options are considered: one that is assumed not to support a reduction of separation minima to 30 nmi/5 min/2000 ft; and one that is assumed to support such a reduction after an evolutionary phase without minima reduction. Both options are assumed to accomplish

Table 5-15A

COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE (1)
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE NAT; BEGIN IMPLEMENTATION 1981
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1980				
1981	1,500,000 (develop, test, spec.)			
1982	1,500,000 (develop, test, spec.)			
1983	2,533,333			
1984	2,533,333			
1985	2,533,333	1,478,000		
1986	14,200,000 (3 sats including ground spare, 2 launches)	1,478,000	100,000	
1987		1,478,000	200,000	
1988	5,700,000 (1 sat, 1 launch)	1,478,000	400,000	250,000
1989			400,000	250,000
1990			400,000	250,000
1991			400,000	250,000
1992			400,000	250,000
1993	11,400,000 (2 sat, 2 launches)		400,000	250,000
1994			400,000	250,000
1995	5,700,000 (1 sat, 1 launch)		400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998			400,000	250,000
1999			400,000	250,000
2000	11,400,000 (2 sat, 2 launches)		400,000	250,000
2001			400,000	250,000
2002	5,700,000 (1 sat, 1 launch)		400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

(1) This table is provided for cost information only, and not used in subsequent cost comparisons.

Table 5-15B

COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE NAT BEGIN IMPLEMENTATION IN 1986
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1985				
1986	1,500,000 (develop, test, spec.)			
1987	1,500,000 (develop, test, spec.)			
1988	2,533,333			
1989	2,533,333			
1990	2,533,333	1,478,000		
1991	14,200,000 (3 sats including ground spare, 2 launches)	1,478,000	100,000	
1992		1,478,000	200,000	
1993	5,700,000 (1 sat, 1 launch)	1,478,000	400,000	250,000
1994			400,000	250,000
1995			400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998	11,400,000 (2 SAT, 2 LAUNCHES)		400,000	250,000
1999			400,000	250,000
2000	5,700,000 (1 sat, 1 launch)		400,000	250,000
2001			400,000	250,000
2002			400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

Table 5-16A

COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE (4)
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT;
BEGIN INSTALLATION IN 1985
(US 1979 Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost (3)
1985	23,758,600	1,904,100	25,662,700	1,112,000
1986	23,758,600	1,904,100	25,662,700	1,138,000
1987	23,758,600	1,904,100	25,662,700	1,165,000
1988	0	1,904,100	1,904,100	1,193,000
1989	0	1,904,100	1,904,100	1,221,000
1990	0	1,904,100	1,904,100	1,250,000
1991	0	1,904,100	1,904,100	1,279,000
1992	0	1,904,100	1,904,100	1,309,000
1993	0	1,904,100	1,904,100	1,340,000
1994	0	1,904,100	1,904,100	1,372,000
1995	0	1,904,100	1,904,100	1,404,000
1996	0	1,904,100	1,904,100	1,437,000
1997	0	1,904,100	1,904,100	1,470,000
1998	0	1,904,100	1,904,100	1,503,000
1999	0	1,904,100	1,904,100	1,538,000
2000	0	1,904,100	1,904,100	1,573,000
2001	0	1,904,100	1,904,100	1,610,000
2002	0	1,904,100	1,904,100	1,647,000
2003	0	1,904,100	1,904,100	1,684,000
2004	0	1,904,100	1,904,100	1,723,000
2005	0	1,904,100	1,904,100	1,763,000
Total	71,275,800	39,986,100	111,261,900	

(1) 422 aircraft/year at $56,300 per aircraft for 3 years.

(2) 34.62 new aircraft per year at $55,000 per aircraft.

(3) Maintenance costs: $1 per use hour

(4) This table is provided for cost information only, and not used in subsequent cost comparisons.

Table 5-16B

COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT;
BEGIN INSTALLATION IN 1990
(US 1979 Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost (3)
1990	27,024,000	1,904,100	28,928,100	1,250,000
1991	27,024,000	1,904,100	28,928,100	1,279,000
1992	27,024,000	1,904,100	28,928,100	1,309,000
1993	0	1,904,100	1,904,100	1,340,000
1994	0	1,904,100	1,904,100	1,372,000
1995	0	1,904,100	1,904,100	1,404,000
1996	0	1,904,100	1,904,100	1,437,000
1997	0	1,904,100	1,904,100	1,470,000
1998	0	1,904,100	1,904,100	1,503,000
1999	0	1,904,100	1,904,100	1,538,000
2000	0	1,904,100	1,904,100	1,573,000
2001	0	1,904,100	1,904,100	1,610,000
2002	0	1,904,100	1,904,100	1,647,000
2003	0	1,904,100	1,904,100	1,684,000
2004	0	1,904,100	1,904,100	1,723,000
2005	0	1,904,100	1,904,100	1,763,000
Total	81,072,000	39,986,100	121,058,100	

(1) 480 aircraft/year at $56,300 per aircraft for 3 years.

(2) 34.62 new aircraft per year at $55,000 per aircraft.

(3) Maintenance costs: $1 per use hour

the following improvements: (1) provide direct pilot-to-controller communications, (2) increase communication reliability (due to signal structure and coding possibilities), (3) provide a basis for implementing automatic dependent surveillance, (4) effect better airspace utilization and increased tactical control (through improvements (1) through (3) above), and (5) reduce the level of labor intensiveness associated with the present voice based system. Both options are assumed to have the same level of ATC automation and display hardware implementation as the network HF and satellite data link and voice system alternatives. The only difference assumed between the two alternatives, from the system design and operational aspects, is that the one without separation minima reduction would have a single unit avionics installation, while the other one which assumes separation minima reduction would have a dual unit installation implemented for the phase with minima reduction, as described below in Section 5.7.2.

For the simple network HF data link and voice system, it has been assumed that aircraft operating within the system would be polled once every five minutes on the average by ground stations (versus the one position report per approximately 40 minute issued by aircraft currently). Such a system could operate within some of the timing and other conventions developed in section 5.2. Air-to-ground and ground-to-air data flow requirements for such a system are developed in Appendix C (see tables C-6, C-7, and C-9).

The simplified HF system was designed to maintain the networking advantages of the current voice system. The simplified system, however, would require far fewer new ground station elements, simplified logic in the airborne component, and fewer communication links between ground staions. In the simplified concept two master control stations, one on either side of the Atlantic, would monitor and control the system, including the assignment of particular aircraft to particular ground stations and frequencies. Each of six ground stations would time share a family of five frequencies.

Since only a single unit avionics installation is assumed for the simple network HF data link and voice without separation minima reduction alternative as outlined in Section 5.7.2, in case of operational data link failure or severe reduction of link reliability the aircraft would revert to SSB voice operation.

Air-ground voice in such a system could utilize residual SSB facilities and operators. The costs of the simple system are estimated assuming a residual SSB radio operator staff is retained for occasional voice communications. It is estimated that present levels of maintenance staff could maintain such a system based on preliminary discussions with ARINC facility personnel operating ACARs, a privately operated VHF air-ground data link system used by some domestic U.S. airline companies.

5.7.2 Airborne System

Avionics required for this system would not contain the sophisticated logic designed into the more complex system of Section 5.2. Costs of such avionics have been estimated based on information obtained from the complex HF network system and consideration of ACARs avionics costs. A single set of ACARs avionics was estimated to cost approximately $10,300 by an airline experienced with installing such equipment (ref. 25). This cost was based on estimates of $4,800 for a management unit, $2000 for a control display unit, $2000 for a printer (which is optional), $600 for installation materials and $900 for installation.

A rough estimate of simple network HF airborne system costs might be made by adding HF modem and system interconnect costs to the $10,300 ACARs costs. An HF modem is estimated to cost $10,000, and interconnection to other systems such as an INS is estimated to cost about $1,000 in additional installation costs. A total rough cost estimate of $21,300 results.

In previous cost estimates of avionics, Working Group B suggested that all essential avionics carried in air transports should be redundant. Hence, a dual installation is assumed for the simple HF data link and voice system with separation minima reduction, which brings the per installation cost to $42,600, a cost almost identical to that estimated in Section 5.2 for a more sophisticated system. Thus, the yearly avionics costs presented in Table 5-1 and Table 5-4 are assumed to apply to the simple network HF system with separation minima reduction. If the system is not vital to safety and if residual SSB voice were considered to provide an adequate backup to a simple HF data link and voice system, it may (at least initially) be reasonable to use only one set of avionics per aircraft. Hence, for the simple HF data link and voice system without separation minima reduction, only a single unit installation at $21,500 per installation is assumed (i.e., half the costs of Table 5-1 and Table 5-4 which is almost equal to the $21,300 roughly estimated in the previous paragraph.

5.7.3 The Ground Stations

Tables 5-17A, 5-17B and 5-17C show the estimated costs of the ground components that the simple HF data link and voice system alternatives would need. These costs were provided by Working Group B of the Aviation Review Committee based on the system design concept developed by the group and summarized in Appendix A.

5.7.4 Summary Simple Network HF Data Link and Voice System Alternatives Costs

A cost of $2,000,000 has been estimated for designing a comprehensive system and drawing up specifications for airborne and ground equipments. This cost assumes that a design is carried out by an average of 10 persons over a three year period (1981, 1982, 1983).

Table 5-17A

Simple Network HF Data Link and Voice System
Radio Station (Cost Per Station)

ITEM	QUANTITY	UNIT COST ($000)	TOTAL COST ($000)
Transmitters 1 (KW) (remotely controllable)	3 + 1	30	120
Transmit Antennas			
Log Periodic (Horizontally Polarised)	3	20	60
Log Periodic (Rotable as Backup)	1	30	30
Transmit Antenna Land Preparation and Installation			
Fixed	3	20	60
Rotatable	1	30	30
Transmit Modem (Coder and Modulator)	1 + 1	5	10
Transmit Control Processor (includes system monitoring)	1 + 1	20	40
Line Modems	4 + 2	2	12
Receivers, Remotely Controllable	5 + 1	4	24
Receive Multicouplers	4	5	20
Receive Antennas			
Log Periodic (Fixed)	3	20	60
Log Periodic (Rotatable)	1	30	30
Receive Antenna, Land Preparation and Installation			
Fixed	3	20	60
Rotatable	1	30	30
Receiver Modems (Demodulators and Decoders)	5 + 1	10	60
Receiver Processor	1 + 1	20	40
Clocks	1 + 1	2	4
Time Code Receivers	1 + 1	3	6
Fault Monitoring System (Probes, Scanning receiver, A to D Card, Control Unit)	1	10	10
Power	7 KW	3/KW	21
Cable	16,000	0.002	32
Remote Equipment Switching	1	10	10
SUB TOTAL			769
TEST EQUIPMENT AND SPARES PLUS 15%			115
TOTAL			884

Note: Indicated costs are considered conservative (i.e., high).

Source: Working Group B, Aviation Review Committee.

Table 5-17B

Simple Network HF Data Link and Voice System Master Control Station (Cost Per Station)

ITEM	QUANTITY	UNIT COST ($000)	TOTAL (COST $000)
Central Processor Unit	2	125	250
Line Modems	6	2	12
Clocks	2	2	4
Time Signal Receivers	2	3	6
Control VDU	2	3	6
CRT Terminal for local and remote fault monitoring	2	3	6
Magnetic disc (including controller)	1	11	11
Sub Total			315
Equipment switching, spares and test equipment etc. 15% of sub total			47
			362

Note: Indicated costs are considered conservative (i.e., high).
Source: Working Group B, Aviation Review Committee

Table 5-17C

Simple Network HF Data Link and Voice System Inter Station Data Circuits

LINK	QUANTITY	UNIT COST ($000)	TOTAL COST $000)
Prestwick to Shannon	2	4	8
Prestwick to Reykjavik	2	38	76
Prestwick to Santa Maria	2	42	84
Prestwik to Gander	2	120	240
New York to Gander	2	40	80
San Juan to Gander	2	70	140
Local lines, ATC Centres to Radio Stations and Receiver Sites to Transmitter Sites	24	0.5	12
PER YEAR TOTAL			640

Source: Working Group B, Aviation Review Committee

Existing ground stations would be enhanced in 1984, 1985, 1986 and 1987 according to the costs shown in Table 5-17A (i.e., $5,304,000 for 6 ground stations), Table 5-17B (i.e., $724,000 for 2 master control stations), and Table 5-17C (i.e., $640,000 per year for maintenance). A $200,000 demonstration program for validating system behavior is assumed to occur in 1987. These costs are summarized in Table 5-18.

Table 5-19A summarizes avionics costs of the Simple HF Data Link and Voice Without Separation Minima Reductions.

Table 5-19B summarizes user costs for a Simple HF Data Link and Voice System With Separation Minima Reduction which requires dual avionics installations. These costs assure that single units are placed in aircraft in the years 1985 through 1989 and thence dual units are installed. Aircraft that had single units installed before 1990 are assumed to have additional units added.

5.8 References

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3. King, K. H., Letter of Transmittal from IATA delineating NAT operator long haul fleets, IATA reference no. 4330, dated June 27, 1980.

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5. Boeing Commercial Airspace Co., "Air Traffic Control Experimentation and Evaluation with the NASA ATS-6 Satellite," Vol. I-VII, Report No. FAA-RD-75,173 (September 1976).

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8. Draft of latest ITU regulations relevant pages obtained from IATA, Montreal, Canada in August 1980.

Table 5-18

SIMPLE NETWORK HF DATA LINK AND VOICE SYSTEM
PROVIDER COSTS FOR GROUND STATION IMPLEMENTATION FOR THE NAT
(1979 US Dollars)

Year	Development and Ground Station Capital Costs		Maintenance	Com Links
1981	666,666	(System design)		
1982	666,666	(System design)		
1983	666,666	(System design)		
1984	1,507,000	(Ground station imp.)		
1985	1,507,000	(Ground station imp.)		
1986	1,507,000	(Ground station imp.)	100,000	640,000
1987	1,707,000	(Ground station imp. and 200,000 demonstration program)	150,000	640,000
1988			200,000	640,000
1989			200,000	640,000
1990			200,000	640,000
1991			200,000	640,000
1992			200,000	640,000
1993			200,000	640,000
1994			200,000	640,000
1995			200,000	640,000
1996			200,000	640,000
1997			200,000	640,000
1998			200,000	640,000
1999			200,000	640,000
2000			200,000	640,000
2001			200,000	640,000
2002			200,000	640,000
2003			200,000	640,000
2004			200,000	640,000
2005			200,000	640,000
Total	8,228,000			

Table 5-19A

SIMPLE NETWORK HF DATA LINK AND VOICE WITHOUT SEPARATION MINIMA REDUCTION
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT
(1979 US Dollars)

Year	Avionics Cost(1)	New Aircraft Cost(2)	Total	Operating Costs(3)
1985	3,891,500	744,330	4,636,830	1,112,000
1986	3,891,500	744,330	4,636,830	1,138,000
1987	3,891,500	744,330	4,636,830	1,165,000
1988	3,891,500	744,330	4,636,830	1,193,000
1989	3,891,500	744,330	4,636,830	1,221,000
1990	3,891,500	744,330	4,636,830	1,250,000
1991	3,891,500	744,330	4,636,830	1,279,000
1992		744,330	744,330	1,309,000
1993		744,330	744,330	1,340,000
1994		744,330	744,330	1,372,000
1995		744,330	744,330	1,404,000
1996		744,330	744,330	1,437,000
1997		744,330	744,330	1,470,000
1998		744,330	744,330	1,503,000
1999		744,330	744,330	1,538,000
2000		744,330	744,330	1,573,000
2001		744,330	744,330	1,610,000
2002		744,330	744,330	1,647,000
2003		744,330	744,330	1,684,000
2004		744,330	744,330	1,723,000
2005		744,330	744,330	1,763,000
Totals	27,240,500	15,630,930	42,871,430	

(1) Retrofit 181 aircraft per year for 7 years at $21,500/aircraft

(2) Added HF costs for 34.62 aircraft.

(3) Operating costs calculated at $1 per operating hour.

Table 5-19B

SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION FOR THE NAT
(1979 US Dollars)

Year	Avionics Cost	New Aircraft Cost	Total	($1/operating hour)
1985	3,891,000(1)	744,330(2)	4,635,830	1,112,000
1986	3,891,500	744,330	4,635,830	1,138,000
1987	3,891,500	744,330	4,635,830	1,165,000
1988	3,891,500	744,330	4,635,830	1,193,000
1989	3,891,500	744,330	4,635,830	1,221,000
1990	7,783,000(3)	1,488,660(4)	9,271,660	1,250,000
1991	19,371,500 (5)	1,488,660	20,860,160	1,279,000
1992	11,588,500(6)	1,488,660	13,077,160	1,309,000
1993		1,488,660	1,488,660	1,340,000
1994		1,488,660	1,488,660	1,372,000
1995		1,488,660	1,488,660	1,404,000
1996		1,488,660	1,488,660	1,437,000
1997		1,488,660	1,488,660	1,470,000
1998		1,488,660	1,488,660	1,503,000
1999		1,488,660	1,488,660	1,538,000
2000		1,488,660	1,488,660	1,573,000
2001		1,488,660	1,488,660	1,610,000
2002		1,488,660	1,488,660	1,647,000
2003		1,488,660	1,488,660	1,684,000
2004		1,488,660	1,488,660	1,723,000
2005		1,488,660	1,488,660	1,763,000
Totals	58,200,500	27,540,210	85,740,710	

(1) Retrofit 181 aircraft with single units at $21,500/year.

(2) Cost for single unit installation on 34.62 new aircraft.

(3) Retrofit 181 aircraft with dual units at $43,000/aircraft.

(4) Cost for dual unit installation on 34.62 new aircraft.

(5) Retrofit 181 aircraft with single units and add unit to 539 aircraft already fit with one unit.

(6) Add unit to 539 aircraft already fit with one unit.

9. Sahmel, R. H., "Aeronautical Satellite Transponder Characteristics and Cost Estimates," Prepared by the Aerospace Corporation for the FAA (August 1980).

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15. ARINC, "Inertial Reference System," ARINC Characteristic 704-1 (April 1, 1980).

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19. Kowalski, S. et al., "Cost Analysis of Airborne Collision Avoidance (CAS) Concepts, Report No. FAA-EM-76-1 (December 1975).

20. FAA informal discussions (September 1980).

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22. ICAO, "Review of the General Concept of Separation (RGCS) Panel, Fourth Meeting, Report on Agenda Item 2," Report No. RGCSP-WP/89.

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25. Telephone conversation with Mr. Gene Huettner, Continental Airlines, October 28, 1980.

6.0 NAT USER FLIGHT COSTS

6.1 Introduction

The user flight operations and maintenance (O&M) costs corresponding to a variety of assumed separation minima in the NAT are estimated in this section. These costs are the aircraft fuel, crew, and maintenance expenditures of flight, excluding the avionics improvement costs described in the preceding section. The cost estimates are based on results obtained from the Flight Cost Model (FCM), a set of computer programs prepared especially for this study. The FCM has been validated by the Aviation Review Committee as a tool for (1) estimating the relative costs among alternative system configurations (where relative costs are the direct flight cost differences associated with operating different system alternatives); and (2) ranking alternative system configurations as to their potential benefits based on relative costs. The validation was based on a comparison of FCM results with actual traffic statistics specially collected for a selected case study day in July 1979.

The FCM user flight cost results presented in this section will be used in subsequent sections to develop and compare the relative costs of the various potential improvements. The data presented below are extracted in part from a companion document (ref. 1) describing the application of the FCM to the NAT and are supported by additional information presented in Appendix D. The FCM model structure is described in ref. 2.

6.2 Flight Cost Model Application

The FCM was used to simulate the operation of the present NAT ATS system and several other system operating alternatives (representing alternative separation minima) on a representative July (peak) day and a representative November (off-peak) day in 1979, and with traffic forecast for the years 1984 and 2005 (ref. 3). The July sample day operation in each of the three sample years was simulated for the various alternatives. The November sample day in each year was simulated only for the 1979 base case system (120-60 nmi/15 min/2000 ft separation minima) for comparison purposes. (Note: References to separation minima are relative to the nominal longitudinal minimum corresponding to the use of constant Mach number technique; e.g., the 60 nmi/10 min/2000 ft system refers to the 10 min longitudinal separation minimum specified for the constant Mach number technique. In all runs of the FCM, the non-Mach number technique separation minimum is assumed to be 5 min greater than the nominal separation indicated. In the previous example, a 15 min minimum is applied by the FCM to aircraft not qualifying for the Mach number technique in the nominal 60 nmi/10 min/2000 ft system.

FCM input statistics were based on data describing actual operations obtained for the July 1979 and November 1979 sample days and forecasts of future traffic loadings. The sample day data include: meteorological information (wind speed and direction and temperature by grid and altitude based on computer tapes obtained from the US National Weather Service); traffic distributions by origin-destination airport pairs flight pattern, departure time, and aircraft type (obtained from published schedules and statistics specially provided by ATS units); planned landing weights (provided by airlines); aircraft fuel burn/weight/altitude performance relationships (provided by airlines); and fuel price and aircraft operating cost data (provided by airlines, user organizations, and published material). Although the July 1979 sample day occurred during a period when US DC-10 aircraft were grounded, the FCM simulation of the scheduled traffic included all DC-10 flights that normally would have been flown on that day; hence, the FCM results were not affected by the DC-10 groundings. The fuel prices were based on the price reported at each of more than 100 origin airports in February 1979 and were inflated by 29% to represent mid-1979 fuel prices in the FCM.

The FCM simulated the various types of flights active in the NAT upper airspace including air carrier, military, and general aviation flights. As part of the simulation process, the FCM developed minimum fuel burn flight plans for each flight based on planned landing weight, weather, route constraints, and flight performance characteristics. The FCM then tracked each flight through domestic and oceanic airspace from takeoff to landing, modeling aircraft movement and potential conflict resolution actions (i.e., diversions and delays), and estimated the fuel burn, flight time, and associated fuel, crew, and maintenance-accrual costs. Representative flight performance characteristics for the following aircraft classes were based on the data provided by airlines and aircraft manufacturers: B747, DC10, L1011, B707, DC8, B747SP, B727 and two proposed future aircraft--a B747 stretch (ST) and a new long narrow body (NEW1) aircraft. Flight performance characteristics for certain other aircraft including air carrier (i.e., mostly IL62 and a few VC10, B720, and DC9 types), military, and general aviation aircraft were not provided, and fuel and time costs for these aircraft were not estimated by the FCM; B707 and B727 flight performance characteristics, as appropriate, were used to simulate the flight profiles of these noncosted air carrier types so as to include their contribution to system traffic. Flight profiles for the military and general aviation aircraft were based on flight strip data. The daily flight cost results produced by the FCM pertain only to the costed flights (i.e., excluding IL62, VC10, B720, DC9, military, and general aviation aircraft) and therefore are slight underestimates of the air carrier direct operating flight expenses for fuel, crew, and maintenance. The traffic distribution is presented in Table 6-1 which shows an 85% increase in costed traffic between 1979 (656 flights) and 2005 (1,219 aircraft) and a 78% increase in total traffic over the same time period (728 versus 1,294 flights).

Table 6-1

NAT TRAFFIC COMPOSITION, JULY SAMPLE DAY

	Traffic Loading		
	1979	1984	2005
Total Number of Flights	728	822	1294
Air Carrier	94%	95%	97%
Military	4%	4%	2%
General aviation	2%	1%	1%
Number of Air Carrier Flights	685	779	1251
Costed air carrier	96%	96%	97%
Number of Costed Air Carrier Flights	656	751	1219
Wide body costed air carrier	50%	76%	95%

The traffic loading data is based on growth factors developed by the traffic forecasting workshop convened by the Aviation Review Committee and documented in reference 3. Also, see section 4.1 of this report for an introductory description of the area and traffic flows covered.

6.3 Overall Costs--July Sample Day

The FCM was used to estimate costs for three modes of flight operation: ideal, planned, and actual flight plan (i.e., routes and altitude profiles). An ideal flight path is simply a flight plan based on domestic route and altitude restrictions and 1000 ft vertical oceanic separation minima with no oceanic route restrictions; in effect, the aircraft is assumed to fly anywhere it wishes in oceanic airspace subject to 1000 ft vertical separation minima. The FCM ideal flight mode estimates the flight costs that would be experienced if each aircraft were to fly an approximately optimum flight path from takeoff to landing. The ideal flight mode simulates a situation in which flights are constrained by domestic routing requirements but are not constrained by OTS routing requirements and are not constrained by lateral and longitudinal separation minima. However, because of limitations due to the FCM program structure and data input complications, ideal mode flights are assumed to fly step-climb profiles (not cruise-climb) subject to 1000 ft vertical separation requirements and hemispheric-type flight rules. The hemispheric rules assume alternating direction of flights on successive 1000 ft flight levels (i.e., all eastbound flights are separated by 2000 ft with a westbound flight level in between).

An FCM planned flight path is a flight plan based on domestic and oceanic route and altitude restrictions with no ATC intervention due to potential conflicts. The FCM planned flight mode estimates the flight costs that would occur if each aircraft were to follow its preferred flight plan.

An FCM actual flight path is a flight route and profile resulting when an aircraft attempts to fly its planned flight path but encounters congestion. The FCM actual flight mode estimates the costs that would be experienced in the real world where separation minima are applied and standard operating procedures are followed. The actual mode assumes that flights would be diverted or delayed to resolve potential violations of separation minima.

The FCM overall NAT cost results for the July sample day are summarized in Table 6-2, which shows the estimated daily fuel, crew, and maintenance-accrual cost totals for all costed aircraft for each system operating alternative in each sample year. The corresponding daily average costs per flight are also shown. The daily cost data shown in Table 6-2 are in 1979 US dollars (i.e., 1979 prices are assumed in future years). For comparison purposes, the cost data shown for future years do not include inflation effects and are not discounted to their 1979 present value.

The operating alternative designated 60 nmi/10 min/1000* ft, which represents a scenario with 1000 ft vertical minimum separation in the NAT oceanic area and 2000 ft elsewhere, was run for the July 1979 sample day. Cost figures shown for 1984 and 2005 in Table 6-2 and subsequent tables for this alternative are interpolations.

Table 6-2

FCM DAILY FLIGHT COSTS, JULY SAMPLE DAY

Year	Flight Operating Mode	Daily Cost by System Operating Alternative							
		120-60 NMI 15 Min. 2000 Ft	60 NMI 15 Min 2000 Ft	60 NMI 10 Min 2000 Ft	30 NMI 10 Min 2000 Ft	30 NMI 5 Min 2000 Ft	60 NMI 15 Min 1000 Ft	60 NMI 10 Min 1000 Ft	60 NMI 10 Min 1000* Ft
		Daily Flight Cost (1979 US $000)†							
1979	Ideal	11002	11002	11002	11002	11002	11002	11002	11002
	Planned	11106	11106	11106	11094	11094	11064	11064	11083
	Actual	11158	11150	11136	11120	11111	11081	11075	11094
1984	Ideal	13702	13702	13702	13702	13702	13702	13702	13702
	Planned	13837	13836	13836	13824	13824	13780	13780	13804
	Actual	13904	13893	13878	13860	13849	13804	13797	13821
2005	Ideal	29327	29327	29327	29327	29327	29327	29327	29327
	Planned	29567	29569	29569	29541	29541	29430	29430	29481
	Actual	29790	29768	29734	29682	29653	29554	29530	29581
		Daily Average Flight Cost (1979 US $000 per Flight)†							
1979	Ideal	16.77	16.77	16.77	16.77	16.77	16.77	16.77	16.77
	Planned	16.93	16.93	16.93	16.91	16.91	16.87	16.87	16.89
	Actual	17.01	17.00	16.98	16.95	16.94	16.89	16.88	16.91
1984	Ideal	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
	Planned	18.42	18.42	18.42	18.41	18.41	18.35	18.35	18.38
	Actual	18.51	18.50	18.48	18.46	18.44	18.38	18.37	18.40
2005	Ideal	24.06	24.06	24.06	24.06	24.06	24.06	24.06	24.06
	Planned	24.26	24.26	24.26	24.23	24.23	24.14	24.14	24.18
	Actual	24.44	24.42	24.39	24.35	24.33	24.24	24.22	24.26

* 1000 ft vertical separation minimum in oceanic airspace, 2000 ft elsewhere.

† Constant 1979 $ US excluding inflation and discount rate.

The ideal flight mode results show that the theoretical minimum daily flight cost regardless of system operating alternative is US$ 11.0 million in 1979 and increases to $13.7 million in 1984 and $29.3 million in 2005. The increase is due to the 85% increase in costed traffic over the 27-year period, as well as a change in fleet mix. The wide body aircraft proportion of costed traffic increases from 50 to 95% over the 1979 to 2005 time period and causes the ideal daily average flight cost to increase from US$ 16,770 to 24,060 per flight over the same period.

6.4 Theoretical Cost Penalties--July Sample Day

The planned flight mode requires aircraft to fly established tracks and route systems in areas where they exist and random tracks elsewhere. The resulting planned costs are affected by route geometric design constraints due to lateral and vertical separation minima, navigation aid locations, and airspace reservations, as well as by the procedures used to define track locations. The actual flight costs include the planned costs and the additional costs caused by necessary ATC intervention (e.g., diversions and delays including refusal of step climb requests).

Because the lowest flight cost attainable is that represented by the ideal cost, the cost differences between the ideal cost and the actual costs represent the maximum possible cost penalties that could theoretically be avoided by any system improvements. These cost penalties for the July sample day are shown in Table 6-3, which presents the total cost difference between planned and ideal costs and between actual and ideal costs. Recall that the costs shown are not inflated and not discounted for comparison purposes.

The Table 6-3 data indicate that the potential daily cost differences associated with planned costs are a majority of the total flight cost penalty. For example, the data for the 60 nmi/10 min/2000 ft system in 1984 show that the estimated planned daily cost difference (US$ 134,000) accounts for 76 % of the difference ($176,000) between ideal and actual daily costs. The planned cost proportion of the actual daily cost penalty ranges from 66 % for the 1979 baseline 120-60 nmi/15 min/2000 ft to 88% for the 60 nmi/10 min/1000 ft system in 1979, but accounts for a lower percentage of actual costs in succeeding years. Note that the lowest cost penalty in each year is associated with the 1000 ft vertical separation minimum.

6.5 System Cost Comparison--July Sample Day

The impact of separation minima reduction is shown in Table 6-4, which presents the difference in daily flight costs between the base case 120-60 nmi/15 min/2000 ft system and each of the other seven system alternatives for the July sample day. The planned daily flight cost

TABLE 6-3

FCM DAILY FLIGHT COSTS RELATIVE TO IDEAL MODE, JULY SAMPLE DAY

Year	Flight Operating Mode	Relative Daily Cost by System Operating Alternative: 120-60 NMI 15 Min 2000 Ft	60 NMI 15 Min 2000 Ft	60 NMI 10 Min 2000 Ft	30 NMI 10 Min 2000 Ft	30 NMI 5 Min 2000 Ft	60 NMI 15 Min 1000 Ft	60 NMI 10 Min 1000 Ft	60 NMI 10 Min 1000* Ft
		Daily Flight Cost Difference Relative to the Ideal Cost in Year Indicated (1979 US $000)†							
1979	Planned	104	104	104	92	92	62	62	81
	Actual	156	148	134	118	109	79	73	92
1984	Planned	135	134	134	122	122	78	78	102
	Actual	202	191	176	158	147	102	95	119
2005	Planned	240	242	242	214	214	103	103	154
	Actual	463	441	407	355	326	227	203	254
		Daily Average Flight Cost Difference Relative to the Ideal Cost in Year Indicated (1979 US $000 per Flight)†							
1979	Planned	0.16	0.16	0.16	0.14	0.14	0.10	0.10	0.12
	Actual	0.24	0.23	0.21	0.18	0.17	0.12	0.11	0.14
1984	Planned	0.17	0.17	0.17	0.16	0.16	0.10	0.10	0.13
	Actual	0.26	0.25	0.23	0.21	0.19	0.13	0.12	0.15
2005	Planned	0.20	0.20	0.20	0.17	0.17	0.08	0.08	0.12
	Actual	0.38	0.36	0.33	0.29	0.27	0.18	0.16	0.20

* 1000 ft vertical separation minimum in oceanic airspace, 2000 ft elsewhere.
† Constant 1979 $ US excluding inflation and discount rate.

TABLE 6-4

FCM DAILY FLIGHT COSTS RELATIVE TO 60-120/15/2000 SYSTEM, JULY SAMPLE DAY

Year	Flight Operating Mode	Relative Daily Cost by System Operating Alternative: 60 NMI 15 Min 2000 Ft	60 NMI 10 Min 2000 Ft	30 NMI 10 Min 2000 Ft	30 NMI 5 Min 2000 Ft	60 NMI 15 Min 1000 Ft	60 NMI 10 Min 1000 Ft	50 NMI 10 Min 1000* Ft
		Daily Flight Cost Difference Relative to 60-120/15/2000 system in year indicated (1979 $000)†						
1979	Planned	0	0	12	12	42	42	23
	Actual	8	22	38	47	77	83	64
1984	Planned	1	1	13	13	57	57	33
	Actual	11	26	44	55	100	107	83
2005	Planned	(2)	(2)	26	26	137	137	85
	Actual	22	56	108	137	236	260	209
		Daily Average Flight Cost Difference Relative to 60-120/15/2000 system in year indicated (1979 $000)†						
1979	Planned	0	0	0.02	0.02	0.06	0.06	0.04
	Actual	0.01	0.03	0.06	0.07	0.12	0.13	0.10
1984	Planned	0	0	0.01	0.01	0.07	0.07	0.04
	Actual	0.01	0.03	0.05	0.07	0.13	0.14	0.11
2005	Planned	0	0	0.03	0.03	0.12	0.12	0.08
	Actual	0.02	0.05	0.09	0.11	0.20	0.22	0.18

* 1000 ft vertical separation minimum in oceanic airspace, 2000 ft elsewhere.
† Constant 1979 $ US excluding inflation and discount rate.

reductions for each of the seven alternatives are calculated relative to the base case system planned cost; the actual daily cost reductions are calculated similarly.

The allocation of cost reductions between planned cost and actual cost savings reflects the impact of track and altitude compaction and longitudinal separation reduction, respectively. The planned daily costs show insignificant reductions from implementation of the 60 nmi lateral spacing, regardless of longitudinal separation. The 60 nmi system does not provide as dramatic a geometric redesign potential relative to the base year 120-60 nmi composite system as do the 30 nmi lateral and 1000 ft vertical options. The redesign potential is demonstrated in 1984 by the $13,000 planned daily cost reduction relative to the 60-120 nmi/15 min/2000 ft when lateral spacings are halved and by the $57,000 reduction when vertical spacings are halved everywhere. Changes in the longitudinal separation minima do not generate planned cost reductions.

The relationship among the various longitudinal, lateral, and vertical separation minima simulated is demonstrated by successive reductions in actual cost as separation minima are reduced. For example, daily cost savings range from $11,000 to $107,000 in 1984 in accordance with separation minima reductions. Of the various system operating alternatives, the 60 nmi/10 min/1000 ft system shows the greatest daily actual cost saving in each year ($83,000, $107,000, and $260,000 in 1979, 1984, and 2005, respectively). In general, the actual daily cost savings achievable by halving vertical separations are greater than twice those achievable by halving lateral separations. In all cases where lateral and vertical separations are fixed, some cost savings are obtained by longitudinal minimum reduction. However, the impacts of longitudinal reductions are proportionately less as lateral and vertical minima are reduced.

6.6 July and November Daily Cost Comparison

The FCM was applied to a November sample using the 120-60 nmi/15 min/2000 ft as a basis for comparing cost magnitudes by year with those of the July sample day. The number of flights in each November sample day is 68% of that in each July sample day, and the daily cost summed over all flights is correspondingly less than in July as shown in Table 6-5. The November 1979 sample day flight cost is 74% of the July 1979 daily cost; this proportion reduces to 66% by the year 2005. Unlike the daily cost statistic, the daily average cost per flight is greater in the November than the July 1979 sample day. This increased cost per aircraft in November versus July 1979 is attributed in part to the difference in the daily meteorological condition and associated OTS setting, and in part to the slight difference in fleet composition; 60%

Table 6-5

FCM COST COMPARISONS FOR NOVEMBER AND JULY SAMPLE DAY
BASED ON 60-120/15/2000 SYSTEM OPERATION

Sample Day	Number of Costed Flights	Daily Flight Cost (Thousands of 1979 US Dollars)	Daily Average Flight Cost Thousands of 1979 US Dollars per flight)
July 1979	656	11,158	17.01
November 1979	449	8,204	18.27
July 1984	751	13,904	18.51
November 1984	512	9,760	19.06
July 2005	1,219	29,790	24.44
November 2005	830	19,548	23.55

of the November sample day costed traffic is composed of widebody aircraft as opposed to 50% in July. However, by the year 2005 the proportion of wide body aircraft in November is the same as July (i.e., 95%), and the July daily average cost per flight becomes greater than that of November due to congestion penalty costs.

6.7 Annual Flight O&M Costs

The daily flight O&M costs discussed in the preceding paragraphs were derived in the FCM by calculating fuel costs separately from crew and maintenance costs and summing the two components. To provide an understanding of the relative magnitude of these two flight O&M cost components, actual average annual flight costs are estimated in terms of both fuel cost and crew and maintenance cost as shown in Table 6-6. These data correspond to the actual costs rather than the ideal or planned costs discussed previously.

Table 6-6 was constructed by calculating the weighted average of the actual daily cost data for the July and November sample days for the indicated year and multiplying the weighted average day by 365. Since resources limited the FCM analysis of the November day to the 1979 year only (recall the July sample day was analyzed in selected future years), the November 1984 and 2005 sample day costs were extrapolated proportionally to the 1979 relationships between July and November daily costs. The extrapolated November daily costs were used to determine the weighted average annual costs shown in Table 6-6. The July versus November weightings were based on the reported annual distribution of traffic. As explained in Appendix D, the calculation of average annual costs assigns a weighting of 35% to the July sample day costs and 65% to the November sample day costs.

The data in Table 6-6 shows that the user total annual flight costs are enormous and increase with traffic growth. Total annual costs range from almost $3,400 million in 1979 to over $8,400 million in 2005. However, the total costs shown for each system alternative in any one year do not vary as dramatically. Although the cost differences between the system alternatives account for a small percentage of the total costs in any one year, these differences are quite large in absolute dollar value and therefore very important to the users. For example, an annual cost difference of nearly 24 million in uninflated 1979 US dollars is shown in Table 6-6 between the 60 nmi/10 min/2000 ft and 60 nmi/10 min/1000 ft operation in 1984. The fuel cost component accounts for virtually all of the total cost difference, because the cost changes attributable to crew and maintenance are insignificant in any one year.

The annual flight O&M costs for each year in the 1979 to 2005 study period for each separation minima operating alternative were estimated by interpolation from the data presented in Table 6-5. A special FCM simulation of the base case 120-60 nmi/15 min/2000 ft operation for the July 1995 sample day augmented the estimation process. The interpolations were calculated using a non-linear compound growth function as

Table 6-6

NAT ANNUAL USER FLIGHT COSTS BASED ON WEIGHTED AVERAGE AND EXTRAPOLATION OF FCM ANALYSIS OF JULY 1979, 1984, AND 2005 AND NOVEMBER 1979 SAMPLE DAYS

System Operating Alternative	Annual Flight O&M Cost by Year (1979 US $ Millions)								
	1979			1984			2005		
	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
120-60 nmi/15 min/2000 ft	2168.47	1203.41	3371.88	2686.04	1405.98	4092.02	5691.81	2751.74	8443.55
60 nmi/15 min/2000 ft	2165.18	1204.50	3369.68	3681.66	1407.08	4088.74	5684.15	2753.20	8437.34
60 nmi/10 min/2000 ft	2161.90	1203.04	3364.94	2678.01	1406.35	4084.36	5676.12	2751.37	8427.49
30 nmi/10 min/2000 ft	2157.88	1202.31	3360.19	2673.99	1405.25	4079.24	5664.80	2748.45	8413.25
30 nmi/5 min/2000 ft	2156.06	1201.95	3358.01	2671.44	1404.89	4076.33	5656.77	2748.09	8404.86
60 nmi/15 min/1000 ft	2144.74	1204.14	3348.88	2656.84	1405.62	4062.46	5624.65	2751.74	8376.39
60 nmi/10 min/1000 ft	2143.28	1203.41	3346.69	2655.01	1405.62	4060.63	5618.81	2751.01	8369.82
60 nmi/10 min/1000*ft	2149.12	1203.41	3352.53	2661.58	1405.98	4067.56	5633.05	2751.37	8384.42

*1000 ft vertical separation minimum in oceanic airspace only, 2000 ft elsewhere.

explained in Appendix D. The resulting estimated annual fuel and crew and maintenance costs are shown in Table 6-7, which lists the flight costs that would be incurred if each system were in operation in the indicated year.

Table 6-7 also includes cost data for a number of separation minima alternatives (i.e., 60 nmi/5 min/2000 ft, 60 nmi/2 min/2000 ft, 60-30 nmi/10 min/2000 ft, 30 nmi/2 min/2000 ft, 15 nmi/10 min/2000 ft, 15 nmi/5 min/2000 ft, and 15 nmi/2 min/2000 ft) that were not simulated by FCM. These non-FCM cost data were estimated by interpolation or, as warranted, extrapolation of the cost data derived from eight cases analyzed by FCM. The estimation procedures are described in Appendix D. The additional separation minima alternatives shown in Table 6-7 were selected because they were considered necessary for the cost analysis of the potential system improvements or for general interest and future reference as necessary.

6.8 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume VII: North Atlantic Region Flight Cost Model Results," Final Report No. FAA-EM-81-17, VII (September 1981).

2. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume IX: Flight Cost Model Description," Final Report No. FAA-EM-81-17, IX (September 1981).

3. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume X: North Atlantic, Central East Pacific, and Caribbean Regions Aviation traffic Forecasts," Final Report No. FAA-EM-81-17, X (September 1981).

Table 6-7

NAT ANNUAL USER FLIGHT O&M COST ESTIMATES
(Millions of 1979 US Dollars)

Year	120-60nmi/15min/2000ft			60nmi/15min/2000ft			60nmi/10min/2000ft		
	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	2168.47	1203.41	3371.88	2165.18	1204.50	3369.68	2161.90	1203.04	3364.94
1980	2263.32	1241.44	3504.76	2259.83	1242.54	3502.37	2256.48	1241.20	3497.68
1981	2362.31	1280.68	3642.99	2358.62	1281.77	3640.39	2355.19	1280.58	3635.77
1982	2465.64	1321.15	3786.79	2461.73	1322.25	3783.98	2458.22	1321.20	3779.42
1983	2573.48	1362.91	3936.39	2569.34	1364.01	3933.35	2565.76	1363.11	3928.87
1984	2686.04	1405.98	4092.02	2681.66	1407.08	4088.74	2678.01	1406.35	4084.36
1985	2791.75	1453.63	4245.38	2787.23	1454.74	4241.97	2783.44	1453.98	4237.42
1986	2901.63	1502.90	4404.53	2896.96	1504.01	4400.97	2893.03	1503.22	4396.25
1987	3015.83	1553.84	4569.67	3011.01	1554.95	4565.96	3006.93	1554.14	4561.07
1988	3134.52	1606.50	4741.02	3129.54	1607.62	4737.16	3125.31	1606.77	4732.08
1989	3257.88	1660.95	4918.83	3252.75	1662.07	4914.82	3248.36	1661.19	4909.55
1990	3386.10	1717.25	5103.35	3380.80	1718.37	5099.17	3376.25	1717.45	5093.70
1991	3519.37	1775.45	5294.82	3513.90	1776.57	5290.47	3509.17	1775.62	5284.79
1992	3657.88	1835.63	5493.51	3652.23	1836.74	5488.97	3647.33	1835.76	5483.09
1993	3801.84	1897.84	5699.68	3796.01	1898.95	5694.96	3790.92	1897.93	5688.85
1994	3951.46	1962.17	5913.63	3945.46	1963.27	5908.73	3940.17	1962.21	5902.38
1995	4106.98	2028.67	6135.65	4100.78	2029.77	6130.55	4095.30	2028.67	6123.97
1996	4243.22	2091.47	6334.69	4236.88	2092.60	6329.48	4231.19	2091.44	6322.63
1997	4383.98	2156.21	6540.19	4377.50	2157.37	6534.87	4371.58	2156.15	6527.73
1998	4529.40	2222.95	6752.35	4522.79	2224.15	6746.94	4516.64	2222.86	6739.50
1999	4679.65	2291.76	6971.41	4672.90	2293.00	6965.90	4666.51	2291.64	6958.15
2000	4834.89	2362.70	7197.59	4829.99	2363.97	7191.96	4821.35	2362.55	7183.90
2001	4995.27	2435.84	7431.11	4988.22	2437.15	7425.37	4981.33	2435.64	7416.97
2002	5160.98	2511.24	7672.22	5153.78	2512.58	7666.37	5146.62	2511.01	7657.63
2003	5332.18	2588.98	7921.16	5324.83	2590.36	7915.19	5317.39	2588.70	7906.09
2004	5509.06	2669.12	8178.18	5501.56	2670.54	8172.10	5493.83	2668.80	8162.63
2005	5691.81	2751.74	8443.55	5684.15	2753.20	8437.35	5676.12	2751.37	8427.49

Table 6-7 (Continued)

Year	60nmi/5min/2000ft Fuel	60nmi/5min/2000ft Crew & Maint.	60nmi/5min/2000ft Total	60nmi/2min/2000ft Fuel	60nmi/2min/2000ft Crew & Maint.	60nmi/2min/2000ft Total	60-30 nmi/10 min/2000 ft Fuel	60-30 nmi/10 min/2000 ft Crew & Maint.	60-30 nmi/10 min/2000 ft Total
1979	2159.30	1202.81	3362.11	2157.41	1202.21	3360.12	2159.60	1203.70	3363.30
1980	2253.73	1240.93	3494.66	2257.31	1240.28	3492.59	2254.33	1241.62	3495.95
1981	2352.30	1280.26	3632.56	2350.84	279.56	3630.40	2353.22	1280.72	3633.94
1982	2455.17	1320.84	3776.01	2453.68	1320.08	3773.76	2456.45	1321.07	3777.52
1983	2562.55	1362.70	3925.25	2561.02	1361.88	3922.90	2564.20	1362.68	3926.88
1984	2674.62	1405.89	4080.51	2673.06	1405.01	4078.07	2676.68	1405.60	4082.28
1985	2779.90	1453.47	4233.37	2778.19	1452.58	4230.77	2781.97	1453.16	4235.13
1986	2889.32	1502.66	4391.98	2887.46	1501.76	4389.22	2891.40	1502.33	4393.73
1987	3003.06	1553.52	4556.58	3001.03	1552.60	4553.63	3005.14	1553.16	4558.30
1988	3121.26	1606.10	4727.36	3119.06	1605.17	4724.23	3123.35	1605.72	4729.07
1989	3244.12	1660.45	4904.57	3241.74	1659.51	4901.25	3246.22	1660.05	4906.27
1990	3371.82	1716.65	5088.47	3369.24	1715.69	5084.93	3373.91	1716.22	5090.13
1991	3504.54	1774.75	5279.29	3501.75	1773.78	5275.53	3506.63	1774.29	5280.92
1992	3642.49	1834.81	5477.30	3639.48	1833.83	5473.31	3644.57	1834.33	5478.90
1993	3785.87	1896.91	5682.78	3782.62	1895.92	5678.54	3787.93	1896.39	5684.32
1994	3934.89	1961.11	5896.00	3931.40	1960.11	5891.51	3936.93	1960.56	5897.49
1995	4089.78	2027.48	6117.26	4086.02	2026.47	6112.49	4091.80	2026.90	6118.70
1996	4225.26	2090.41	6315.67	4221.37	2089.33	6310.70	4227.41	2089.53	6316.94
1997	4365.22	2155.30	6520.52	4361.20	2154.13	6515.33	4367.51	2154.09	6521.60
1998	4509.82	2222.19	6732.01	4505.66	2220.95	6726.61	4512.26	2220.64	6732.90
1999	4659.22	2291.17	6950.39	4654.91	2289.84	6944.75	4661.80	2289.25	6951.05
2000	4813.56	2362.29	7175.85	4809.10	2360.86	7169.96	4816.30	2359.99	7156.29
2001	4973.01	2435.61	7408.62	4968.40	2434.09	7402.49	4975.92	2432.90	7408.82
2002	5137.74	2511.21	7648.95	5132.98	2509.59	7642.57	5140.83	2508.07	7648.90
2003	5307.94	2589.15	7897.09	5303.00	2587.43	7890.43	5311.21	2585.57	7896.78
2004	5483.77	2669.52	8153.29	5478.66	2667.69	8146.35	5487.23	2665.45	8152.68
2005	5665.42	2752.38	8417.80	5660.14	2750.43	8410.57	5669.09	2747.81	8416.90

Table 6-7 (Continued)

Year	30 nmi/10 min/2000 ft Fuel	Crew & Maint.	Total	30 nmi/5 min/2000 ft Fuel	Crew & Maint.	Total	30nmi/2 min/2000ft Fuel	Crew & Maint.	Total
1979	2157.88	1202.31	3360.19	2156.06	1209.95	3358.01	2154.43	1201.31	3355.74
1980	2252.44	1240.41	3492.85	2250.49	1240.05	3490.54	2248.76	1239.43	3488.19
1981	2351.15	1279.71	3630.86	2349.06	1279.35	3628.41	2347.22	1278.77	3625.99
1982	2454.18	1320.26	3774.44	2451.95	1319.90	3771.85	2450.00	1319.35	3769.35
1983	2561.73	1362.09	3923.82	2559.34	1361.73	3921.07	2557.27	1361.22	3918.49
1984	2673.99	1405.25	4079.24	2671.44	1404.89	4076.33	2669.24	1404.42	4073.66
1985	2779.17	1452.80	4231.97	2776.45	1452.44	4228.89	2774.14	1451.99	4226.13
1986	2888.49	1501.97	4390.46	2885.58	1501.60	4387.18	2883.16	1501.16	4384.32
1987	3002.11	1552.80	4554.91	2999.01	1552.43	4551.44	2996.47	1552.00	4548.47
1988	3120.20	1605.34	4725.54	3116.89	1604.98	4721.87	3114.22	1604.57	4718.79
1989	3242.94	1659.67	4902.61	3239.41	1659.30	4898.71	3236.61	1658.91	4895.52
1990	3370.50	1715.83	5086.33	3366.74	1715.47	5082.21	3363.81	1715.10	5078.91
1991	3503.08	1773.90	5276.98	3499.08	1773.53	5272.61	3496.00	1773.19	5269.19
1992	3640.87	1833.93	5474.80	3636.62	1833.56	5470.18	3633.39	1833.24	5466.63
1993	3784.09	1895.99	5680.08	3779.56	1895.62	5675.18	3776.18	1895.33	5671.51
1994	3932.94	1960.15	5893.09	3928.13	1959.79	5887.92	3924.58	1959.52	5884.10
1995	4087.64	2026.48	6114.12	4082.53	2026.12	6108.65	4078.81	2025.89	6104.70
1996	4223.22	2089.18	6312.40	4217.87	2088.82	6306.69	4213.95	2088.61	6302.56
1997	4363.30	2153.83	6517.13	4357.70	2153.47	6511.17	4353.56	2153.28	6505.84
1998	4508.02	2220.48	6728.50	4502.16	2220.11	6722.27	4497.80	2219.95	6717.75
1999	4657.55	2289.[illegible]	6946.73	4651.41	2288.82	6940.23	4646.82	2288.68	6935.50
2000	4812.03	2360.02	7172.05	4805.61	2359.65	7165.26	4800.78	2359.54	7160.32
2001	4971.64	2433.04	7404.68	4964.93	2432.68	7397.61	4959.84	2432.59	7392.43
2002	5136.54	2508.33	7644.87	5129.52	2507.96	7637.48	5124.16	2507.91	7632.07
2003	5306.92	2585.94	7892.86	5299.55	2585.58	7885.13	5293.94	2585.56	7879.50
2004	5482.94	2665.96	8148.90	5475.26	2665.60	8140.86	5469.33	2665.61	5735.94
2005	5664.80	2748.45	8413.25	5656.77	2748.09	8404.86	5650.54	2748.14	8398.68

Table 6-7 (Continued)

Year	15 nmi/10 min/2000 ft			15nmi/5min/2000ft			15nmi/2min/2000ft		
	Fuel	Crew & Maint.	Total	Fuel	Crew& Maint.	Total	Fuel	Crew & Maint.	Total
1979	2153.82	1201.91	3355.73	2152.00	1201.31	3353.30	2151.09	1200.72	3351.81
1980	2248.27	1239.98	3488.25	2246.40	1239.38	3485.78	2245.38	1238.84	3484.22
1981	2346.86	1279.26	3626.12	2344.94	1278.66	3623.60	2343.80	1278.18	3621.98
1982	2449.77	1319.78	3769.55	2447.81	1319.18	3766.99	2446.53	1318.76	3765.29
1983	2557.19	1361.58	3918.77	2555.18	1360.99	3916.17	2553.77	1360.63	3914.40
1984	2669.33	1404.71	4074.04	2667.27	1404.12	4071.39	2665.71	1403.83	4069.54
1985	2774.28	1452.27	4226.55	2772.13	1451.67	4223.80	2770.48	1451.39	4221.87
1986	2883.35	1501.43	4384.78	2881.12	1500.84	4381.96	2879.37	1500.57	4379.94
1987	2996.71	1552.27	4548.98	2994.39	1551.67	4546.06	2992.54	1551.41	4543.95
1988	3114.53	1604.82	4719.35	3112.12	1604.22	4716.34	3110.16	1603.97	4714.13
1989	3236.98	1659.15	4896.13	3234.47	1658.55	4893.02	3232.40	1658.32	4890.72
1990	3364.24	1715.32	5079.56	3361.64	1714.72	5076.36	3359.44	1714.50	5073.94
1991	3496.51	1773.40	5269.91	3493.80	1772.80	5212.60	3491.48	1772.59	5264.07
1992	3633.98	1833.44	5467.42	3631.16	1832.84	5464.00	3628.71	1832.65	5461.36
1993	3776.85	1895.51	5672.36	3773.92	1894.91	5668.83	3771.33	1894.74	5666.07
1994	3925.34	1959.68	5885.02	3922.29	1959.09	5881.38	3919.56	1958.94	5878.50
1995	4079.67	2026.03	6105.75	4076.50	2025.44	6101.94	4073.61	2025.31	6098.92
1996	4214.80	2088.70	6303.50	4211.37	2088.11	6299.48	4208.31	2087.92	6296.28
1997	4354.41	2153.30	6507.71	4350.70	2152.71	6503.41	4347.42	2152.56	6500.03
1998	4498.65	2219.91	6718.56	4494.65	2219.31	6713.96	4491.22	2219.16	6710.38
1999	4647.66	2288.57	6936.23	4643.35	2287.98	6931.33	4639.73	2287.81	6927.54
2000	4801.60	2399.36	7160.96	4796.98	2358.77	7155.75	4793.16	2358.59	7151.75
2001	4960.65	2432.34	7392.99	4955.68	2431.75	7387.43	4951.65	2431.56	7383.21
2002	5124.96	2507.57	7632.53	5119.64	2506.98	7626.62	5115.39	2506.78	7622.17
2003	5294.72	2585.13	7879.85	5289.03	2584.55	7873.58	5284.54	2584.33	7868.87
2004	5470.10	2665.10	8135.20	5464.01	2664.51	8128.52	5459.28	2664.28	8123.56
2005	5651.29	2747.53	8398.82	5644.79	2746.95	8391.74	5639.80	2746.71	8386.52

Table 6-7 (Concluded)

Year	60nmi/15min/1000ft Fuel	Crew & Maint.	Total	60/nmi/10min/1000ft Fuel	Crew & Maint.	Total	60nmi/10min/1000* ft Fuel	Crew & Maint.	Total
1979	2144.74	1204.14	3348.88	2143.28	1203.41	3346.69	2149.12	1203.41	3352.53
1980	2238.58	1241.98	3480.56	2237.05	1241.38	3478.43	2243.04	1241.44	3484.48
1981	2336.53	1281.01	3617.54	2334.93	1280.55	3615.48	2341.06	1280.68	3621.74
1982	2438.76	1321.27	3760.03	2437.09	1320.95	3758.04	2443.36	1321.15	3764.51
1983	2545.47	1362.79	3908.26	2543.72	1362.63	3906.35	2550.14	1362.91	3913.05
1984	2656.84	1405.62	4062.46	2655.01	1405.62	4060.63	2661.58	1405.98	4067.56
1985	2761.25	1453.27	4214.52	2759.30	1453.25	4212.55	2766.14	1453.59	4219.73
1986	2869.77	1502.54	4372.31	2867.68	1502.49	4370.17	2874.80	1502.80	4377.60
1987	2982.55	1553.47	4536.02	2980.33	1553.40	4533.73	2987.74	1553.69	4541.43
1988	3099.77	1606.14	4705.91	3097.39	1606.03	4703.42	3105.11	1606.29	4711.40
1989	3221.59	1660.59	4882.18	3219.06	1660.45	4879.51	3227.09	1660.68	4887.77
1990	3348.20	1716.88	5065.08	3345.51	1716.71	5062.22	3353.87	1716.91	5070.78
1991	3479.78	1775.09	5254.87	3476.92	1774.88	5251.80	3485.62	1775.04	5260.66
1992	3616.53	1835.26	5451.79	3613.49	1835.02	5448.51	3622.55	1835.15	5457.70
1993	3758.66	1897.48	5656.14	3755.43	1897.20	5652.63	3764.86	1897.28	5662.14
1994	3906.38	1961.80	5868.18	3902.94	1961.48	5864.42	3912.76	1961.52	5874.28
1995	4059.90	2028.31	6088.21	4056.25	2027.94	6084.19	4066.47	2027.94	6094.41
1996	4194.43	2091.13	6285.56	4190.60	2090.73	6281.33	4201.17	2090.76	6291.93
1997	4333.43	2155.90	6489.33	4329.41	2155.47	6484.88	4340.33	2155.53	6495.86
1998	4477.02	2222.68	6699.70	4472.81	2222.22	6695.03	4484.10	2222.30	6706.40
1999	4625.38	2291.52	6916.90	4620.96	2291.03	6911.99	4632.63	2291.15	6923.78
2000	4778.65	2362.49	7141.14	4774.02	2361.97	7135.99	4786.09	2362.12	7148.21
2001	4937.00	2435.67	7372.67	4932.15	2435.11	7367.26	4944.62	2435.29	7379.91
2002	5100.60	2511.11	7611.71	5095.52	2510.51	7606.03	5108.41	2510.73	7619.14
2003	5269.62	2588.89	7858.51	5264.30	2588.25	7852.55	5277.62	2588.51	7866.13
2004	5444.24	2669.07	8113.31	5438.67	2668.39	8107.06	5452.44	2668.70	8121.14
2005	5624.65	2751.74	8376.39	5618.81	2751.01	8369.82	5633.05	2751.37	8384.42

* 1000 ft vertical separation minima in oceanic airspace only; 2000 ft elsewhere

7.0 NAT PROVIDER FACILITIES COSTS

7.1 Introduction

The ATS unit and COM station facilities operated by the NAT provider authorities require capital and annual O&M expenditures that include labor and related direct and indirect operating costs. These ATS and COM facilities expenditures, excluding the capital and O&M expenses for potential improvements previously described in Section 5 are estimated in this section for the present system and alternative operations.

7.2 ATS Unit Annual O&M Costs

7.2.1 Present System

Estimates of the annual O&M cost of providing ATS at the various ATS units for 1979 have been presented in an accompanying document describing the present system (ref. 1). These units include the Shanwick Oceanic Area Control Center (OACC) and the Gander, New York, Santa Maria, Reykjavik, San Juan and Miami ACCs. The estimates were based in part on data provided by some provider authorities and in part on assumptions concerning the level of expenditures at sites where cost data were not available. The O&M cost estimates for the US facilities were based on data which did not include certain overhead costs. The cost estimates are shown in Table 7-1. The staff category shown in Table 7-1 refers to the annual personnel costs associated with ATS. The other direct operating cost category refers to the nonstaff annual expenditures required to maintain ATS, and include such items as parts and supplies, leases, and electricity. The indirect cost category includes such items as depreciation, interest payments, and insurance premiums. In conformance with the standard cost reporting procedures used by the various provider authorities, the depreciation and interest payments represent annualized equipment costs; therefore, the indirect O&M costs in Table 7-1 include capital equipment annual cost allocations.

In order to account for overhead costs not included in the previous cost estimates for the US facilities, the O&M costs are assumed to be on the order of almost double those originally estimated in Reference 1. This assumption obtains an estimate of about $7 million for the US O&M costs, which, when added to the non-US ATS O&M cost, obtains an estimate of $21 million for the NAT facilities in 1979. Note that if the assumption of doubling the US O&M preliminary cost estimate is inaccurate, the estimated O&M total costs will not significantly distort subsequent comparisons of improvement option costs because these comparisons will be made relative to the present system costs (i.e., cost differences will be calculated relative to a common baseline).

Table 7-1

NAT ATS 1979 PRESENT SYSTEM O&M COST ESTIMATES
(Thousands of 1979 US Dollars)

Expenditure	Gander ACC	Shanwick OACC	New York ACC*	Santa Maria ACC	Reykjavik ACC	San Juan ACC*	Miami ACC*	Total†
Staff Cost	3486	4191	2700*	410	512	708*	280*	12,287†
Other Direct Operating Cost	2072	2491	125*	56	70	32*	17*	4,863†
Indirect Operating Cost	336	404	75*	47	59	20*	10*	951†
Total	5894	7086	2900*	513	641	760*	307*	18,101†

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* These Cost estimates do not include certain overhead costs, see text.

† These total costs do not reflect certain U.S. facility overhead costs, see note above.

The O&M costs are expected to increase gradually during the 1979 to 2005 study period, primarily because of the increase in staffing and equippage required to serve the traffic growth projected during this time period. Although the rate of growth cannot be predicted with high precision, the increase in O&M requirements is expected to be proportional to traffic growth. NAT traffic, based on peak day daily costed traffic estimates, is projected to increase by 85% during the 1979 to 2005 period, which corresponds to a 2.4% annually compounded rate of growth. This growth rate is assumed to apply to the future annual O&M costs of the present system.

The question arises as to how future annual O&M costs will be affected by currently planned near-term ATC automation. While the implementation of ATC automation would affect O&M costs, the degree of this impact is not clear. For example, the implementation of electronic flight data displays and conflict prediction automation would alleviate controller workload and possibly requirements for staff growth. Further, the advanced solid state technology associated with ATC automation might involve lower unit maintenance costs than current electromechanical technology such as that employed in flight strip printers. However, the expansion of software and hardware capabilities, which would be necessitated by ATC automation, implies expansion in maintenance requirements. Lacking further information, it is assumed that efficiencies gained in ATS automation will be counterbalanced by the increased maintenance costs due to the enlarged technological scope of automation enhancements and that the 2.4% annually compounded O&M cost growth rate is appropriate for present system continuance beginning with a $21 million O&M cost in 1979. The resulting O&M costs are shown in Table 7-2.

7.2.2 Alternative Operations

ATS unit O&M costs will be affected by communication and associated surveillance system improvements. Specifically, the introduction of either automatic dependent surveillance or cooperative independent surveillance will require implementation of automated ATC data handling, controller displays, and associated advanced ATC automation software and hardware at each ATS unit. These improvements will be more advanced than the near-term automation improvements associated with present system continuance, and will require capital expenses for research, development, testing and evaluation (RDT&E) and equipment installation which are estimated in the following paragraphs. Annual O&M costs also are addressed.

RDT&E Capital Costs--Informal discussions with FAA personnel addressed the potential costs of a single RDT&E program that would be required to support the implementation of automated ATC data handling, controller display and associated advanced ATC automation features at US oceanic ATS facilities. Based on the costs of analogous programs, it was estimated that the RDT&E program might cost about $5 million. Furthermore, it was assumed that separate RDT&E program costs for each

Table 7-2

NAT ATS UNIT PROVIDER COST ESTIMATES
(Millions of 1979 US Dollars)

	Present System Continuance	Automatic Dependent Surveillance§		Independent Cooperative Surveillance	
Year	Annual O&M*	Capital†	Annual O&M*	Capital†	Annual O&M*
1979	21.0				
1980	21.5				
1981	22.0				
1982	22.5				
1983	23.1	5.0			
1984	23.6	5.0			
1985	24.2	5.0			
1986	24.8	5.0			
1987	25.4	8.0	25.4		
1988	26.0		26.0	5.0	
1989	26.6		26.6	5.0	
1990	27.3		27.3	5.0	
1991	27.9		27.9	5.0	
1992	28.6		28.6	9.0	28.6
1993	29.3		29.3		29.3
1994	30.0		30.0		30.0
1995	30.7	1.0	30.7		30.7
1996	31.4		31.4		31.4
1997	32.2		32.2		32.2
1998	33.0		33.0		33.0
1999	33.7		33.7		33.7
2000	34.6	1.0	34.6	1.0	34.6
2001	35.4		35.4		35.4
2002	36.2		36.2		36.2
2003	37.1		37.1		37.1
2004	38.0		38.0		38.0
2005	38.9	1.0	38.9	1.0	38.9

*Indicated values are based on a 2.4% annual compound growth rate starting with the present system 1979 cost.

†Indicated values include a $20.0 million 4-year development program, $8.0 million (or $9 million) initial equipment purchase cost and $1.0 million periodic equipment expansion costs; all capital costs assume a 20-year recovery life.

§Indicated values apply to simple network HF, network HF, satellite data link and voice, and satellite data link only.

of the Gander and Shanwick ATS units would be about the same as those of the US costs and that separate program costs for each of the Santa Maria and Reykjavik ATS units would be about half of the US costs. As a result of these assumptions, the NAT total RDT&E costs are estimated to be $20 million.

Equipment Capital Costs--The costs of equipment installations at the oceanic facilities include the automated ATC data handling, controller displays, related advanced ATC automation software and hardware, and direct air-ground communication equipment expenditures required for either automatic dependent surveillance or independent cooperative surveillance operations. Discussions with FAA personnel found that a current domestic digitized radar sector with flight strip data processing might cost about $250 thousand, including $50 thousand for the direct air-ground sector console communication equipment. Assuming that the proposed oceanic automation would offer controllers potential conflict intervention capabilities that are not part of the present strategic control procedures, the automated equipment is expected to involve advanced tabular and graphical traffic display capabilities. Lacking further information describing the details of the automated oceanic sector design, the equipment installation costs are assumed to be similar to those of current radar sector costs and equal to $250 thousand per sector. This assumption is made with the understanding that the future oceanic displays would not be identical to current radar data presentations, but that the data processing and display complexities inherent in automatic dependent surveillance (using network HF, simple network HF, satellite data link and voice, or satellite data link only) or cooperative independent surveillance (using multiple satellite data link and voice) with automation enhancements might be of the same level of complexity as current digitized radar data processing and display.

The installation costs depend on the number of sectors involved and the year of operational implementation, and are estimated as follows. The seven NAT ATS units operated about 25 sectors in 1979 assuming shared CAR and NAT operations at the San Juan and Miami ACCs. Assuming that automatic dependent surveillance operations using network HF or satellite data link could be initiated in 1990, and allowing for a 2.4% annual compound growth rate in sectorization, 32 sectors would be required in 1990 at a cost of $8 million. The 32 sector equipment units are assumed to be purchased and installed in 1987 to allow time for a two year operational shakedown in 1988 and 1989. Allowing for continued sectorization growth at the 2.4% rate, four additional sectors are assumed to be required every five years at a cost of $1 million in each of 1995, 2000 and 2005. This enhancement plan also applies to the simple network HF data link and voice, which might initiate partial data link services without separation minima reduction in 1987 and might later evolve to reduced minima operations.

Capital Cost Summary--The resulting capital installation costs associated with automatic dependent surveillance using network HF, simple network HF or satellite data link and voice are shown in Table 7-2 as are the RDT&E capital costs. The RDT&E cost of $20 million is assumed to be distributed over the four year period from 1983 through 1986. All capital expenses are assumed to involve a 20 year recovery life.

Similar capital cost estimates are shown in Table 7-2 for the cooperative independent surveillance using multiple satellite data link and voice except that operations are assumed to be initiated in 1995 with an initial purchase of 36 sector equipment units in 1992 at a cost of $9 million. The four year $20 million RDT&E program is assumed to begin in 1988.

O&M Costs--The enhancement of controller conflict intervention capabilities associated with automatic dependent surveillance and independent cooperative surveillance might imply a more intensive control work environment than currently exists in terms of increased surveillance, intervention decision-making, and communication requirements per aircraft. But, the introduction of advanced data handling, display and associated features would automate parts of the controller work routine, and hence could prevent increases in controller workload and associated staff growth. Furthermore, future reductions in separation minima from those of the present system would reduce the frequency of potential conflict events, hence alleviating controller workload. For the purposes of this study, the reductions in workload associated with automation are assumed to offset any increases associated with new operating strategies in the future, and, therefore, the staff required for the automated operations are assumed to be the same as that required for present system continuance.

Apart from controller staffing costs, maintenance costs might be increased because of the enlarged technological scope of the automation enhancements. But, these costs may be offset by more efficient diagnostic and preventive maintenance practices. These considerations lead to the assumption that the annual O&M costs of automatic dependent surveillance or independent cooperative surveillance might be about the same as those of present system continuance. This assmption is supported by the accounting procedure used to estimate present system O&M costs which allocated the annualized capital costs of the present system to the indirect O&M cost category. Since the annualized capital costs of present system sectorization should be discontinued when an alternative operation is implemented, the reduction in O&M costs would offset any residual increase in maintenance costs that might result from technological enlargement.

The ATS annual O&M cost estimates for the 1979 to 2005 time period are listed in Table 7-2 for the automatic dependent surveillance and cooperative independent surveillance alternatives. These costs assume

that the dependent and independent systems are separately developed; that is, either one system or the other is developed but not both concurrently.

Annual O&M costs and implementation schedule for the simple HF data link and voice operation are assumed to be the same as those of the network HF data link and voice operation. Therefore, the annual O&M costs of the simple HF data link are represented by the automatic dependent surveillance costs shown in Table 7-2.

7.3 COM Station Annual O&M Costs

7.3.1 Present System

Estimates of the 1979 O&M costs for the Gander, Shanwick, New York, Santa Maria, Gufunes, San Juan and Miami COM stations have been prepared (ref. 2) and are presented in Table 7-3. The total NAT 1979 O&M cost is shown to be $9.8 million. Following the logic presented in the preceding paragraphs, the O&M costs of continuing the present system are assumed to increase at a 2.4% annually compounded growth rate.

7.3.2 Alternative Systems

Costs as shown in Table 7-3 for the existing COM stations would change with the implementation of any type of automated data link system. If an HF data link were used, for example, the new links used for interfacility transfer of data would effectively carry some data that currently are carried by leased lines. Hence, if either a network HF data link or satellite data link system were implemented, the leased line costs are assumed to be reduced by approximately 50%, which would result in a 10% reduction in the total yearly cost shown in Table 7-3. (Note that to avoid double counting, the O&M costs of any new links that have been included in the O&M costs estimated for the improvement item are not included in this section.)

Additional cost changes associated with new systems would result from a reduced need for radio operators and maintenance personnel. If an automatic dependent surveillance with a network HF data link and voice system was introduced, the radio operator labor function would be significantly reduced to provide for the occasionally used voice function. An 80% reduction in radio operator costs is assumed (excluding leased lines), which is equivalent to a 48% reduction in total yearly costs for HF stations. The total decrease of yearly communication O&M costs shown in Table 7-3 would thus be 58% (10% for leased line reduction and 48% for radio operator labor) of the present system costs if HF data link were introduced. Therefore, HF system annual O&M costs would be 42% of the annual O&M costs shown in Table 7-3.

Table 7-3

NAT COM PRESENT SYSTEM O&M COST ESTIMATES
(Thousands of 1979 US Dollars)

Expenditure	Gander	Shanwick	Gufunes	Santa Maria	New York	San Juan	Total
Labor, (e.g., radio operators, and administration	1782.5	1535.2	1006.5	688.0	641.2	278.5	5881.9
Direct operating costs	535.2	461.4	302.2	192.5	192.7	83.7	1767.7
Indirect costs	28.8	24.2	16.2	9.9	10.1	4.4	93.6
Leased lines (AFTN and AFS)	852.1	99.8	409.9	237.6	237.6	211.2	2048.2
Total	3198.6	2120.6	1734.8	1078.0	1081.6	577.8	9791.4

It is assumed that if an automatic dependent surveillance with satellite data link and voice system or a cooperative independent surveillance with multiple satellites was implemented, six small HF communication stations (similar in size to the San Juan station) would be retained to support a residual HF voice network. The San Juan station is estimated to cost $0.367 million per year to operate exclusive of leased line costs, as shown in Table 7-3. Six stations would cost $2.202 million to operate in 1979. With the additional assumption that leased line costs are halved to $1.024 million, total annual costs would be $3.226 million, or 33% of the present system 1979 total annual O&M cost ($9.791 million). This relationship is assumed to apply to future annual costs.

The resulting NAT COM station total annual O&M cost estimated for the 1979 to 2005 time period are shown in Table 7-4 for the present system continuance; automatic dependent surveillance with network HF data link and voice, satellite data link and voice, and satellite data link only; and the cooperative independent surveillance with multiple satellites data link and voice. The estimated annual costs shown in Table 7-4 would be required if the respective systems were in operation in the year indicated.

Table 7-4 also shows the estimated annual costs for simple network HF data link and voice (with or without separation minima reduction). In this case, the data link operation is assumed to be gradually introduced, starting in 1987 and reaching full service in 1992 when the aircraft fleet is assumed to be fully equipped with at least the single unit avionics of the simple network HF data link and voice system. To account for the transition from present system to full simple network HF data link and voice operaions, a linear reduction in COM stations annual O&M costs is assumed during 1987 through 1991 as shown in Table 7-4. The annual costs shown from 1992 through 2005 are the same as those estimated for the automatic dependent surveillance with network HF data link and voice. Subsequent implementation of dual avionics and reduced separation minima with the simple network HF data link and voice system would not change the COM station O&M costs shown in Table 7.4.

7.4 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume II: North Atlantic Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, II (September 1981).

2. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume V: North Atlantic, Central East Pacific and Caribbean Regions Communication Systems Descriptions," Final Report No. FAA-EM-81-17, V (September 1981)

Table 7-4

NAT COM FACILITY ANNUAL O&M COST ESTIMATES

(Millions of 1979 US Dollars)

Year	Present System Continuance*	Automatic Dependent Surveillance with Network HF Data Link & Voice†	Automatic Dependent Surveillance with Satellite Data Link and Voice or Data Link Only‡	Cooperative Independent Surveillance with Multiple Satellite Data Link and Voice‡	Automatic Dependent Surveillance with Simple Network HF Data Link and Voice§
1979	9.80				
1980	10.04				
1981	10.28				
1982	10.52				
1983	10.78				
1984	11.03				
1985	11.30				
1986	11.57				
1987	11.85				10.58
1988	12.13				9.58
1989	12.42				8.58
1990	12.72	5.34	4.20		7.59
1991	13.03	5.47	4.30		6.60
1992	13.34	5.60	4.40		5.60
1993	13.66	5.74	4.51		5.74
1994	13.99	5.88	4.62		5.88
1995	14.32	6.01	4.73	4.73	6.01
1996	14.67	6.16	4.84	4.84	6.16
1997	15.02	6.31	4.96	4.96	6.31
1998	15.38	6.46	5.08	5.08	6.46
1999	15.75	6.62	5.20	5.20	6.62
2000	16.13	6.77	5.32	5.32	6.77
2001	16.51	6.93	5.45	5.45	6.93
2002	16.91	7.10	5.58	5.58	7.10
2003	17.32	7.27	5.72	5.72	7.27
2004	17.73	7.45	5.85	5.85	7.45
2005	18.16	7.63	5.99	5.99	7.63

*Indicated values are based on a 2.4% compound annual growth rate.

†Each indicated value is equal to 42% of the corresponding present system continuance costs.

‡Each indicated value is equal to 33% of the corresponding present system continuance costs.

§Each indicated value in 1992 through 2005 is equal to 42% of the corresponding present system continuance cost, and each value in 1987 through 1991 is based on a linear transition from the present system ($11.57 million in 1986) to full improvement ($5.60 million in 1992).

8.0 NAT POTENTIAL IMPROVEMENT CONFIGURATIONS AND COSTS

8.1 Introduction

The various potential improvements introduced and discussed in the preceding sections may be implemented individually or in combination. The improvement configurations obtainable depend on the technical and operational feasibility of implementing the various improvements in meaningful sequences and on the capability of the resulting combinations to achieve reduced separation minima and economic benefits. This section describes the configurations that were selected and their costs.

8.2 Potential Improvement Configurations

A preliminary set of improvement configurations was defined based on logical evolutionary deployments of the various system improvements beginning with the present system operation in 1979. This set of configurations was reviewed and revised by the Aviation Review Committee as summarized in Appendix G. The Committee identified the following potential improvement configuraions for further study; each configuration is defined in terms of its technical components, operating requirements and separation minima subject to the condition that the baseline configuration's separation minima (i.e., the Configuration 1 minima) are in effect until the year indicated:

(1) Configuration 1. Baseline, HF SSB Voice, MNPS, 120-60 nmi/15min/2000 ft through 1980, 60 nmi/15 min/, 2000 ft in 1981, 60 nmi/10 min/2000 ft in 1982 through 2005

(2) Configuration 2. 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 through 2005

(3) Configuration 3. 60-30 Composite, HF SSB Voice, MNPS (Improved) and/or Improved Vertical Performance, 60-30 nmi/10 min/2000 ft in 1985 through 2005

(4) Configuration 4. 1000 ft Vertical Separation Above FL 290 Oceanic Only, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005

(5) Configuration 5. 1000 ft Vertical Separation Above FL 290 Oceanic Only With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005

(6) Configuration 6. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1985 through 2005

(7) Configuration 7. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic With Improved Altimetry, HF SSB Voice, PS (Vertical), 60 nmi/10 min/1000 ft in 1988 through 2005

(8) Configuration 8. Airborne Separation Assurance Device With 100% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005

(9) Configuration 9. Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, HF SSB Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005

(10) Configuration 10. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005

(11) Configuration 11. Configuration 10 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005

(12) Configuration 12. Simple Network HF Data Link and Voice Without Separation Minima Reduction, MNPS, 60 nmi/10 min/2000 ft in 1987 through 2005

(13) Configuration 13. Simple Network HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30 nmi/5 min/2000 ft in 1993 through 2005

(14) Configuration 14. Configuration 13 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1993 through 2005

(15) Configuration 15. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005

(16) Configuration 16. Configuration 15 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005

(17) Configuration 17. Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30 nmi/5 min/2000 ft in 1990 through 2005

(18) Configuration 18. Configuration 17 + Airborne Separation Assurance Device with 50% Avionics Capital Cost Allocation, 30 nmi/5 min/2000 ft in 1990 through 2005

(19) Configuration 19. Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice, MNPS (Advanced), 15 nmi/2 min/2000 ft in 1995 through 2005

(20) Configuration 20. Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane, 15 nmi/2 min/2000 ft in 1995 through 2005

(21) Configuration 21. Configuration 19 + 60-30 Composite, HF SSB Voice, MNPS, 60-30 nmi/10 min/2000 ft in 1985 and 15 nmi/2 min/2000 ft in 1995 through 2005

The preceding list does not enumerate all possible configurations, but it identifies implementation sequences that are judged by the Aviation Review Committee to be practical and reasonably representative of the broad range of alternatives available. Table 8-1 summarizes each configuration's components, separation minima and support requirements.

The following paragraphs briefly describe the improvement implementations proposed in each configuration and the capital and operating and maintenance costs associated with the implementation sequences. The costs are tabulated in Tables 8-2 through 8-22 and are based on the expenditure data given in Sections 5, 6, and 7. The capital costs indicated in these tables by year of expenditure are syntheses of development, purchase and installation cost estimates presented in Section 5 for both providers and users, and provider ATS unit capital costs presented in Section 7. The O&M costs for potential improvements are derived from the Section 5 data for providers and users, and the ATS and COM facilities O&M costs are obtained from Section 7 data. The user O&M costs are extracted from Section 6.

Table 8-1

NAT POTENTIAL IMPROVEMENT CONFIGURATIONS

Configuration Components*	Separation Minima Evolution	Support Requirements*
Configuration 1. Baseline	120-60 nmi/15 min/2000 ft, OTS & 120 nmi/15 min/2000 ft, elsewhere: 1979 & 1980 60 nmi/15 min/2000 ft: 1981 60 nmi/10 min/2000 ft: 1982-2005	MNPS; HF SSB
Configuration 2. Baseline + 60-30 Composite	Baseline separation minima: 1979-1984 60-30 nmi/10 min/2000 ft, OTS & 60 nmi/10 min/2000 ft, elsewhere: 1985-2005	MNPS; HF SSB
Configuration 3. Baseline + 60-30 Composite	Baseline separation minima: 1979-1988 60-30 nmi/10 min/2000 ft, OTS & 60 nmi/10 min/2000 ft, elsewhere: 1989-2005	MNPS; HF SSB + MNPS (Improved) and/or improved vertical performance
Configuration 4. Baseline + 1000 ft Vertical Oceanic Only	Baseline separation minima: 1979-1984 60 nmi/10 min/1000 ft: 1985-2005	MNPS; HF SSB + PS (Vertical)
Configuration 5. Baseline + 1000 ft Vertical Oceanic Only With Improved Altimetry	Baseline separation minima: 1979-1987 60 nmi/10 min/1000 ft: 1988-2005	MNPS; HF SSB + PS (Vertical)
Configuration 6. Baseline + 1000 ft Vertical Oceanic & Domestic	Baseline separation minima: 1979-1984 60 nmi/10 min/1000 ft: 1985-2005	MNPS; HF SSB + PS (Vertical)
Configuration 7. Baseline + 1000 ft Vertical Oceanic & Domestic With Improved Altimetry	Baseline separation minima: 1979-1987 60 nmi/10 min/1000 ft: 1988-2005	MNPS; HF SSB + PS (Vertical)
Configuration 8. Baseline + Separation Assurance Device With 100% Avionics Capital Cost Allocation	Baseline separation minima: 1979-1989 30 nmi/5 min/2000 ft: 1990-2005	MNPS; HF SSB + MNPS (Improved)
Configuration 9. Baseline + Separation Assurance Device With 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979 1989 30 nmi/5 min/2000 ft: 1990-2005	MNPS; HF SSB + MNPS (Improved)

Table 8-1 (Continued)

Configuration Components	Separation Minima Evolution	Support Requirements*
Configuration 10. Baseline + ADS With Network HF	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 11. Baseline + ADS With Network HF + Separation Assurance Device With 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 12. Baseline + Simple Network HF Without Reduced Separation Minima	Baseline separation minima: 1979–2005	MNPS; HF SSB + Direct air-ground and Advanced ATC information processing
Configuration 13. Baseline + Simple Network HF With Reduced Separation Minima	Baseline separation minima: 1979–1992 30 nmi/5 min/2000 ft: 1993–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 14. Baseline + Simple Network HF With Reduced Separation Minima + Separation Assurance Device With 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979–1992 30 nmi/5 min/2000 ft: 1993–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 15. Baseline + ADS With Satellite	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Improved), Direct air-ground and Advanced ATC information processing

Table 8-1 (Continued)

Configuration Components	Separation Minima Evolution	Support Requirements*
Configuration 16. Baseline + ADS With Satellite + Separation Assurance Device With 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 17. Baseline + ADS With Satellite, Data Link Only	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 18. Baseline + ADS with Satellite, Data Link Only + Separation Assurance Device with 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979–1989 30 nmi/5 min/2000 ft: 1990–2005	MNPS; HF SSB + MNPS (Imporved); Direct air-ground and Advanced ATC information processing
Configuration 19. Baseline + CIS With Multiple Satellite	Baseline separation minima: 1979–1994 15 nmi/2 min/2000 ft: 1995–2005	MNPS; HF SSB + MNPS (Advanced); Direct air-ground and Advanced ATC information processing
Configuration 20. Baseline + CIS With Multiple Satellite + Free Flight in Vertical Plane	Baseline separation minima: 1979–1994 15 nmi/2 min/2000 ft: 1995–2005	MNPS; HF SSB + MNPS (Advanced); Direct air-ground and Advanced ATC information processing + Revised ATC clearance control procedures

Table 8-1 (Concluded)

Configuration Components	Separation Minima Evolution	Support Requirements*
Configuration 21. Baseline + 60-30 Composite	Baseline separation minima: 1979-1984 60-30 nmi/10 min/2000 ft, OTS & 60 nmi/10 min/2000 ft, elsewhere: 1985-1994	MNPS; HF SSB
+ CIS With Multiple Satellite	15 nmi/2 min/2000 ft: 1995-2005	+ MNPS (Advanced); Direct air-ground and Advanced ATC information processing

*HF SSB = High-frequency single sideband pilot-radio operator air-ground voice communication
Direct air-ground = Direct pilot-controller data link and or voice link or both
Advanced ATC information processing = Automated ATC data handling, controller displays, and associated advanced ATC automation
MNPS = Minimum Navigation Performance Specification
PS = Performance Specification
ADS = Automatic Dependent Surveillance
CIS = Cooperative Independent Surveillance
Network HF = Network HF data link and voice
Simple Network HF = Simple Network HF data link and voice
Satellite = Satellite data link and voice
Multiple Satellite = Mulitple satellite data link and voice
Separation Assurance Device = Airborne separation assurance device

8.2.1 Configuration 1. Baseline

The baseline configuration represents the continuation of present system technology and operational strategies using MNPS and HF SSB pilot-radio operator air-ground voice communication. Because potential system improvements beyond those currently planned are not associated with this configuration, capital and O&M costs for technological change are not involved. However, COM station and ATS unit O&M costs associated with present system continuation would be incurred and are assumed to include all costs resulting from proposed near-term automation. Current plans for separation minima application are to: (1) continue the 1979 120-60 nmi/15 min/2000 ft composite separations on the OTS tracks and 120 nmi/15 min/2000 ft separations elsewhere in the NAT into 1980; (2) establish 60 nmi/15 min/2000 ft separations in OTS and non-OTS MNPS airspace by 1981; and (3) apply 60 nmi/10 min/2000 ft separations in 1982 and subsequent years. These separations assume continuation of the present system MNPS standard, which includes a 6.3 nmi one sigma lateral navigation accuracy specification, with allowance for expansion of MNPS airspace coverage within the total NAT area. The user flight O&M costs (i.e., fuel, crew, and maintenance costs) listed in Table 8-2 represent the annual costs associated with the specific separation minima planned for the indicated year.

8.2.2 Configuration 2 and 3. 60-30 Composite with MNPS or MNPS (Improved) and/or Improved Vertical Performance

The conditions outlined previously in Section 4.3 pertaining to the 60-30 nmi composite structure must be resolved prior to its implementation. In this regard, the Aviation Review Committee concurred on the assumption that the agreed MNPS criteria (rather than adjustment of the separation minima based on observed navigation performance at a given time) would be used to justify a 60-30 composite structure. States are, at present, certifying aircraft to fly in the NAT MNPS airspace based upon the MNPS criteria and not on a particular level of aggregated observed performance. If significant changes in observed performance were to occur, it was assumed that the MNPS criteria would be changed in an orderly manner to reflect new information (ref. 1).

The OTS lateral separation minima perhaps might be reduced in the future to a 60-30 nmi composite by international agreement without any concurrent changes in technology and operating requirements; i.e., with continuation of the present system's MNPS and HF SSB pilot-radio operator air-ground voice communication. Implementation of a 60-30 nmi composite OTS operation in this case would be a continuation of past practices by which the routine, ongoing aircraft position monitoring and data gathering activities in the NAT have historically been the basis for justifying certain reductions in separation. Allowing for the time required to reach agreement through the existing international formats and agendas, the baseline separation minima are assumed to be in effect through 1984 with the 60-30 nmi/10 min/2000 ft OTS minima and 60 nmi

TABLE 8-2
COST SUMMARY FOR NAT CONFIGURATION 1:
BASELINE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.988	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2783.44	1453.98	4237.42	35.500	4237.418	4272.914	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	0.000	0.000	0.000	2893.03	1503.22	4396.25	36.370	4396.250	4432.617	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	0.000	0.000	0.000	3006.93	1554.14	4561.07	37.250	4561.066	4598.313	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.000	0.000	0.000	3125.31	1606.77	4732.08	38.130	4732.078	4770.207	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.000	0.000	0.000	3248.36	1661.19	4909.55	39.020	4909.547	4948.566	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.000	0.000	0.000	3376.25	1717.45	5093.70	40.020	5093.699	5133.719	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.000	0.000	0.000	3509.17	1775.62	5284.79	40.930	5284.789	5325.719	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.000	0.000	0.000	3647.33	1835.76	5483.09	41.940	5483.090	5525.027	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.000	0.000	0.000	3790.92	1897.93	5688.85	42.960	5688.848	5731.805	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.000	0.000	0.000	3940.17	1962.21	5902.38	43.990	5902.379	5946.367	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.000	0.000	0.000	4095.30	2028.67	6123.97	45.020	6123.969	6168.988	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.000	0.000	0.000	4231.19	2091.44	6322.63	46.070	6322.629	6368.695	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.000	0.000	0.000	4371.58	2156.15	6527.73	47.220	6527.727	6574.945	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.000	0.000	0.000	4516.64	2222.86	6739.50	48.380	6739.500	6787.879	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.000	0.000	0.000	4666.51	2291.64	6958.15	49.450	6958.148	7007.598	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.000	0.000	0.000	4821.35	2362.55	7183.90	50.730	7183.898	7234.625	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.000	0.000	0.000	4981.33	2435.64	7416.96	51.910	7416.965	7468.871	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.000	0.000	0.000	5146.62	2511.01	7657.63	53.110	7657.629	7710.738	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.000	0.000	0.000	5317.39	2588.70	7906.09	54.420	7906.090	7960.508	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.000	0.000	0.000	5493.83	2668.80	8162.63	55.730	8162.625	8218.352	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.000	0.000	0.000	5676.12	2751.37	8427.49	57.060	8427.488	8484.547	2005

non-OTS lateral minimum applied in the 1985 through 2005 time period for Configuration 2. The corresponding user flight costs are listed in Table 8-3 along with the COM and ATS facility O&M costs of continuing the present services. Improvement capital and O&M costs would not be required by this configuration.

The Aviation Review Committee in assessing Configuration 2 (in which the current MNPS criteria for lateral navigation accuracy is assumed) agreed that by using current assumptions for vertical performance in conjunction with MNPS requirements, a 60-30 composite track structure would not, with certainty, assume an acceptable level of safety. The Committee concluded accordingly that the likelihood of achievement of Configuration 2 was less than that of Configuration 3 which assumes the application of MNPS (Improved) and/or improved vertical performance (i.e., as demonstrated or obligatory by a performance standard) and continuation of HF SSB pilot-radio operator air-ground voice communication (ref. 1).

Configuration 3, as defined by the Aviation Review Committee, is based on the assumption that changes in the current MNPS criteria could be achieved and/or changes in the vertical performance assumptions could be justified such as to make a 60-30 composite route structure viable. Three possibilities for such changes were identified:

(1) Improvements of lateral performance including incidence of large deviations and subsequent amendment of the MNPS criteria to the point where no changes were required to the current vertical performance assumptions (but it should be noted that during discussions at the ICAO 9th Air Navigation Conference the point had been made that it was not desirable that changes to MNPS criteria be made within a time period of ten years from their inception, viz. from December 1977).

(2) Demonstration, by means of an adequate data collection program, that the vertical performance was sufficiently good that the currently used vertical overlap assumptions were invalid, and that the effects of the high probability of lateral overlap of 30 nmi could be reduced to an acceptable level when combined with the probable vertical overlap.

(3) A combination of (1) and (2): i.e., a reduction in the lateral MNPS criteria and a reduction of the vertical overlap assumptions to the point where the combination would provide an acceptable level of safety (ref. 1).

Allowing time for the implementation of 60-30 nmi composite operations through ongoing position monitoring, data gathering and analysis, and international agreement, the application of the 60-30 nmi/ 10 min/2000 ft separation minima is assumed to occur in 1985. The corresponding user flight O&M costs, and the COM and ATS facility O&M costs

TABLE 8-3
COST SUMMARY FOR NAT CONFIGURATION 2:
60-30 COMPOSITE WITH MNPS

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.988	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2781.97	1453.16	4235.13	35.500	4235.129	4270.625	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	0.000	0.000	0.000	2891.40	1502.33	4393.73	36.370	4393.727	4430.094	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	0.000	0.000	0.000	3005.14	1553.16	4558.30	37.250	4558.297	4595.543	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.000	0.000	0.000	3123.35	1605.72	4729.07	38.130	4729.066	4767.195	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.000	0.000	0.000	3246.22	1660.05	4906.27	39.020	4906.270	4945.289	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.000	0.000	0.000	3373.91	1716.22	5090.13	40.020	5090.129	5130.148	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.000	0.000	0.000	3506.63	1774.29	5280.92	40.930	5280.918	5321.848	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.000	0.000	0.000	3644.57	1834.33	5478.90	41.940	5478.898	5520.836	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.000	0.000	0.000	3787.93	1896.39	5684.32	42.960	5684.316	5727.273	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.000	0.000	0.000	3936.93	1960.56	5897.49	43.990	5897.488	5941.477	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.000	0.000	0.000	4091.80	2026.90	6118.70	45.020	6118.699	6163.719	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.000	0.000	0.000	4227.41	2089.53	6316.94	46.070	6316.938	6363.004	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.000	0.000	0.000	4367.51	2154.09	6521.60	47.220	6521.602	6568.820	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.000	0.000	0.000	4512.26	2220.64	6732.90	48.380	6732.898	6781.277	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.000	0.000	0.000	4661.80	2289.25	6951.05	49.450	6951.051	7000.500	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.000	0.000	0.000	4816.30	2359.99	7176.29	50.730	7176.289	7227.016	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.000	0.000	0.000	4975.92	2432.90	7408.82	51.910	7408.820	7460.727	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.000	0.000	0.000	5140.83	2508.07	7648.89	53.110	7648.895	7702.004	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.000	0.000	0.000	5311.21	2585.57	7896.78	54.420	7896.777	7951.195	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.000	0.000	0.000	5487.23	2665.45	8152.68	55.730	8152.680	8208.406	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.000	0.000	0.000	5669.09	2747.81	8416.90	57.060	8416.898	8473.957	2005

would be the same as those of Configuration 2 and are listed in Table 8-4; recall these costs are the same as those of the baseline configuration. Note that the cost estimates for Configuration 3 assume that additional data gathering expenses would not be required beyond those of the presently conducted data gathering and analysis efforts.

8.2.3 Configuration 4. 1000 ft Vertical Separation Above FL 290 Oceanic Only

Reduction in the vertical separation minimum to 1000 ft above FL 290 in oceanic airspace only without technological improvements might be justified by the results of a special data gathering and analysis program. The 1000 ft minimum would be established by international agreement and, according to the Aviation Review Committee consensus (see Section 4), would require the establishment of a vertical performance specification--PS (Vertical)--analogous to MNPS assuming continuation of HF SSB pilot-radio operator air-ground voice communication and MNPS. Allowing for the time required to reach international agreement, the baseline operation is assumed to be in effect through 1984 and the 1000 ft separation rule is assumed to be implemented in 1985 and continued thereafter. The corresponding user flight O&M costs and provider capital costs for the special study are presented in Table 8-5. The COM and ATS facility O&M costs are assumed to be the same as those of the baseline configuration.

8.2.4 Configuration 5. 1000 ft Vertical Separation Above FL 290 Oceanic Only With Improved Altimetry

The study may show that the altimetry systems and height- keeping accuracy of current altimetry systems cannot justify reductions to a 1000 ft vertical separation minimum above FL 290. In such a case, implementation of improved altimetry and height-keeping systems (e.g., special equipment calibration programs, new altimetry systems, altitude hold systems, or possibly radar altimetry for use in oceanic areas) and establishment of PS (Vertical) would be necessary to support the vertical separation reduction with continuation of HF SSB pilot-radio operator voice communications and MNPS. Allowing time for implementation of the improvements, the baseline system is assumed to be in effect through 1988 and the 1000 ft separation above FL 290 is assumed to be implemented in 1989 and continued thereafter. The corresponding provider and user capital and O&M costs are presented in Table 8-6. The COM and ATS facility O&M costs are assumed to be the same as those of the baseline configuration.

8.2.5 Configurations 6 and 7. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic Airspace Either With or Without Improved Altimetry (and Height-Keeping Capabilities)

TABLE 8-4
COST SUMMARY FOR NAT CONFIGURATION 3:
60-30 COMPOSITE WITH MNPS(I)

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.968	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2781.97	1453.16	4235.13	35.500	4235.129	4270.625	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	0.000	0.000	0.000	2891.40	1502.33	4393.73	36.370	4393.727	4430.094	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	0.000	0.000	0.000	3005.14	1553.16	4558.30	37.250	4558.297	4595.543	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.000	0.000	0.000	3123.35	1605.72	4729.07	38.130	4729.066	4767.195	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.000	0.000	0.000	3246.22	1660.05	4906.27	39.020	4906.270	4945.289	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.000	0.000	0.000	3373.91	1716.22	5090.13	40.020	5090.129	5130.148	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.000	0.000	0.000	3506.63	1774.29	5280.92	40.930	5280.918	5321.848	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.000	0.000	0.000	3644.57	1834.33	5478.90	41.940	5478.898	5520.836	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.000	0.000	0.000	3787.93	1896.39	5684.32	42.960	5684.316	5727.273	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.000	0.000	0.000	3936.93	1960.56	5897.49	43.990	5897.488	5941.477	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.000	0.000	0.000	4091.80	2026.90	6118.70	45.020	6118.699	6163.719	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.000	0.000	0.000	4227.41	2089.53	6316.94	46.070	6316.938	6363.004	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.000	0.000	0.000	4367.51	2154.09	6521.60	47.220	6521.602	6568.820	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.000	0.000	0.000	4512.26	2220.64	6732.90	48.380	6732.898	6781.277	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.000	0.000	0.000	4661.80	2289.25	6951.05	49.450	6951.051	7000.500	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.000	0.000	0.000	4816.30	2359.99	7176.29	50.730	7176.289	7227.016	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.000	0.000	0.000	4975.92	2432.90	7408.82	51.910	7408.820	7460.727	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.000	0.000	0.000	5140.83	2508.07	7648.89	53.110	7648.895	7702.004	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.000	0.000	0.000	5311.21	2585.57	7896.78	54.420	7896.777	7951.195	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.000	0.000	0.000	5487.23	2665.45	8152.68	55.730	8152.680	8208.406	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.000	0.000	0.000	5669.09	2747.81	8416.90	57.060	8416.898	8473.957	2005

TABLE 8-5

COST SUMMARY FOR NAT CONFIGURATION 4:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	1.500	0.000	1.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	35.380	3928.870	3964.250	1983
1984	1.500	0.000	1.500	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	36.130	4084.360	4120.488	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2766.14	1453.59	4219.73	35.500	4219.727	4255.223	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	0.000	0.000	0.000	2874.80	1502.80	4377.60	36.370	4377.598	4413.965	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	0.000	0.000	0.000	2987.74	1553.69	4541.43	37.250	4541.430	4578.676	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.000	0.000	0.000	3105.11	1606.29	4711.40	38.130	4711.398	4749.527	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.000	0.000	0.000	3227.09	1660.68	4887.77	39.020	4887.770	4926.789	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.000	0.000	0.000	3353.87	1716.91	5070.78	40.020	5070.777	5110.797	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.000	0.000	0.000	3485.62	1775.04	5260.66	40.930	5260.660	5301.590	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.000	0.000	0.000	3622.55	1835.15	5457.70	41.940	5457.699	5499.637	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.000	0.000	0.000	3764.86	1897.28	5662.14	42.960	5662.137	5705.094	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.000	0.000	0.000	3912.76	1961.52	5874.28	43.990	5874.277	5918.266	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.000	0.000	0.000	4066.47	2027.94	6094.41	45.020	6094.406	6139.426	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.000	0.000	0.000	4201.17	2090.76	6291.93	46.070	6291.930	6337.996	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.000	0.000	0.000	4340.33	2155.53	6495.86	47.220	6495.855	6543.074	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.000	0.000	0.000	4484.10	2222.30	6706.40	48.380	6706.398	6754.777	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.000	0.000	0.000	4632.63	2291.15	6923.78	49.450	6923.777	6973.227	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.000	0.000	0.000	4786.09	2362.12	7148.21	50.730	7148.207	7198.934	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.000	0.000	0.000	4944.62	2435.29	7379.91	51.910	7379.910	7431.816	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.000	0.000	0.000	5108.41	2510.73	7619.14	53.110	7619.137	7672.246	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.000	0.000	0.000	5277.62	2588.51	7866.13	54.420	7866.129	7920.547	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.000	0.000	0.000	5452.44	2668.70	8121.14	55.730	8121.141	8176.867	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.000	0.000	0.000	5633.05	2751.37	8384.42	57.060	8384.418	8441.477	2005

TABLE 8-6
COST SUMMARY FOR NAT CONFIGURATION 5:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.26	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	1.500	0.000	1.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	35.380	3928.870	3964.250	1983
1984	1.500	0.000	1.500	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	36.130	4084.360	4120.488	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	4.393	0.022	4.415	2783.44	1453.98	4237.42	35.500	4241.832	4277.328	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	4.393	0.046	4.439	2893.03	1503.22	4396.25	36.370	4400.688	4437.055	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	4.393	0.068	4.461	3006.93	1554.14	4561.07	37.250	4565.527	4602.773	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.173	0.070	0.243	3105.11	1606.29	4711.40	38.130	4711.641	4749.770	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.173	0.072	0.245	3227.09	1660.68	4887.77	39.020	4888.012	4927.031	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.173	0.074	0.247	3353.87	1716.91	5070.78	40.020	5071.023	5111.043	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.173	0.075	0.248	3485.62	1775.04	5260.66	40.930	5260.906	5301.836	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.173	0.077	0.250	3622.55	1835.15	5457.70	41.940	5457.949	5499.887	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.173	0.079	0.252	3764.86	1897.28	5662.14	42.960	5662.387	5705.344	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.173	0.081	0.254	3912.76	1961.52	5874.28	43.990	5874.531	5918.520	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.173	0.082	0.255	4066.47	2027.94	6094.41	45.020	6094.660	6139.680	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.173	0.084	0.257	4201.17	2090.76	6291.93	46.070	6292.184	6338.250	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.173	0.086	0.259	4340.33	2155.53	6495.86	47.220	6496.113	6543.332	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.173	0.088	0.261	4484.10	2222.30	6706.40	48.380	6706.656	6755.035	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.173	0.089	0.262	4632.63	2291.15	6923.78	49.450	6924.039	6973.488	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.173	0.091	0.264	4786.09	2362.12	7148.21	50.730	7148.469	7199.195	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.173	0.093	0.266	4944.62	2435.29	7379.91	51.910	7380.176	7432.082	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.173	0.094	0.267	5108.41	2510.73	7619.14	53.110	7619.402	7672.512	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.173	0.096	0.269	5277.62	2588.51	7866.13	54.420	7866.395	7920.813	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.173	0.098	0.271	5452.44	2668.70	8121.14	55.730	8121.410	8177.137	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.173	0.100	0.273	5633.05	2751.37	8384.42	57.060	8384.688	8441.746	2005

The discussions presented in the preceding paragraphs apply to Configurations 6 and 7 except that the scope of the improvement includes domestic airspace in addition to oceanic airspace. Configurations 6 and 7 would obviate any potential problems of transition into domestic airspace that may occur in Configurations 4 and 5. The Aviation Review Committee noted that such transition problems may be difficult to overcome (ref. 1).

The impact of the expanded geographic scope of the reduced vertical minimum on user flight O&M costs is included in Tables 8-7 and 8-8 for the two configurations; that is, the tables show lower user flight cost with 1000 ft vertical separation above FL 290 implemented in the oceanic and domestic airspaces rather than in only oceanic airspace, as anticipated.

8.2.6 Configurations 8 and 9. Airborne Separation Assurance Device With Either 100% or 50% Avionics Capital Cost Allocation

The airborne separation assurance device in conjunction with improved navigation and continuation of HF SSB pilot-radio operator voice communication would be a possible means for achieving 30 nmi lateral and 5 min longitudinal separation minima subject to agreement on the operational suitability of the device. Such acceptability would depend on the ability of the ATS system to operate at the reduced minima with an acceptable low frequency of potential collision avoidance maneuvers. In accordance with the operating requirements described in Section 4, the reduced minima would require more precise system-wide navigation performance than currently exists and would be expected to require more stringent MNPS standards. Specifically, the reduction to 30 nmi/5 min/2000 ft separation minima is expected to require an MNPS (Improved) standard compatible with an onboard navigation system accuracy of about 3 nmi, one sigma (as opposed to the current 6.3 nmi one sigma MNPS standard; the Aviation Review Committee also considered slightly larger one sigma values, including 3.65 nmi (ref. 1). These levels of navigation accuracy are assumed to be within the capabilities of the current generation of avionics equipment with allowances for near-term refinements.

The value of a separation assurance device is primarily to compensate for the prospective effect of large errors on collision risk. That is, as noted by the Aviation Review Committee, systems such as the airborne separation assurance device must not be used to compensate for deficiencies in normal navigation performance, and thus the distribution of deviations from track due to normal navigation performance must be contained, except for the smallest residue, within half of the lateral separation. Airborne separation assurance could not prevent the occurrence of wide deviations off track for whatever reason (large errors and blunders), but by appropriate warnings, could afford protection against the potential collision risk so caused (ref. 1).

TABLE 8-7
COST SUMMARY FOR NAT CONFIGURATION 6: 1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	1.500	0.000	1.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	35.380	3928.870	3964.250	1983
1984	1.500	0.000	1.500	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	36.130	4084.360	4120.488	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2759.30	1453.25	4212.55	35.500	4212.547	4248.043	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	0.000	0.000	0.000	2867.68	1502.49	4370.17	36.370	4370.168	4406.535	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	0.000	0.000	0.000	2980.33	1553.40	4533.73	37.250	4533.727	4570.973	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.000	0.000	0.000	3097.39	1606.03	4703.42	38.130	4703.418	4741.547	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.000	0.000	0.000	3219.06	1660.45	4879.51	39.020	4879.508	4918.527	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.000	0.000	0.000	3345.51	1716.71	5062.22	40.020	5062.219	5102.238	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.000	0.000	0.000	3476.92	1774.88	5251.80	40.930	5251.797	5292.727	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.000	0.000	0.000	3613.49	1835.02	5448.51	41.940	5448.508	5490.445	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.000	0.000	0.000	3755.43	1897.20	5652.63	42.960	5652.629	5695.586	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.000	0.000	0.000	3902.94	1961.48	5864.42	43.990	5864.418	5908.406	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.000	0.000	0.000	4056.25	2027.94	6084.19	45.020	6084.188	6129.207	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.000	0.000	0.000	4190.60	2090.73	6281.33	46.070	6281.328	6327.395	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.000	0.000	0.000	4329.41	2155.47	6484.88	47.220	6484.879	6532.098	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.000	0.000	0.000	4472.81	2222.22	6695.03	48.380	6695.027	6743.406	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.000	0.000	0.000	4620.96	2291.03	6911.99	49.450	6911.988	6961.438	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.000	0.000	0.000	4774.02	2361.97	7135.99	50.730	7135.988	7186.715	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.000	0.000	0.000	4932.15	2435.11	7367.26	51.910	7367.258	7419.164	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.000	0.000	0.000	5095.52	2510.51	7606.03	53.110	7606.027	7659.137	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.000	0.000	0.000	5264.30	2588.25	7852.55	54.420	7852.551	7906.969	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.000	0.000	0.000	5438.67	2668.39	8107.06	55.730	8107.059	8162.785	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.000	0.000	0.000	5618.81	2751.01	8369.82	57.060	8369.816	8426.875	2005

TABLE 8-8

COST SUMMARY FOR NAT CONFIGURATION 7:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
WITH IMPROVED ALTIMETRY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	1.500	0.000	1.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	35.380	3928.870	3964.250	1983
1984	1.500	0.000	1.500	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	36.130	4084.360	4120.488	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	4.393	0.022	4.415	2783.44	1453.98	4237.42	35.500	4241.832	4277.328	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	4.393	0.046	4.439	2893.03	1503.22	4396.25	36.370	4400.688	4437.055	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	4.393	0.068	4.461	3006.93	1554.14	4561.07	37.250	4565.527	4602.773	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.173	0.070	0.243	3097.39	1606.03	4703.42	38.130	4703.660	4741.789	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.173	0.072	0.245	3219.06	1660.45	4879.51	39.020	4879.750	4918.770	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.173	0.074	0.247	3345.51	1716.71	5062.22	40.020	5062.465	5102.484	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.173	0.075	0.248	3476.92	1774.88	5251.80	40.930	5252.043	5292.973	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.173	0.077	0.250	3613.49	1835.02	5448.51	41.940	5448.758	5490.695	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.173	0.079	0.252	3755.43	1897.20	5652.63	42.960	5652.879	5695.836	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.173	0.081	0.254	3902.94	1961.48	5864.42	43.990	5864.672	5908.660	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.173	0.082	0.255	4056.25	2027.94	6084.19	45.020	6084.441	6129.461	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.173	0.084	0.257	4190.60	2090.73	6281.33	46.070	6281.582	6327.648	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.173	0.086	0.259	4329.41	2155.47	6484.88	47.220	6485.137	6532.355	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.173	0.088	0.261	4472.81	2222.22	6695.03	48.380	6695.285	6743.664	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.173	0.089	0.262	4620.96	2291.03	6911.99	49.450	6912.250	6961.699	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.173	0.091	0.264	4774.02	2361.97	7135.99	50.730	7136.250	7186.977	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.173	0.093	0.266	4932.15	2435.11	7367.26	51.910	7367.523	7419.430	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.173	0.094	0.267	5095.52	2510.51	7606.03	53.110	7606.293	7659.402	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.173	0.096	0.269	5264.30	2588.25	7852.55	54.420	7852.816	7907.234	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.173	0.098	0.271	5438.67	2668.39	8107.06	55.730	8107.328	8163.055	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.173	0.100	0.273	5618.81	2751.01	8369.82	57.060	8370.086	8427.145	2005

Taking into account development, demonstration, and equippage requirements, the separation assurance device and MNPS (Improved) are assumed to be implemented for operational shake-down by 1988. Allowing for a 2-year operational shake-down and refinement period, the 30 nmi/5 min/2000 ft minima are assumed to be implemented in 1990 with the baseline separation minima operating during the preceding 1979 through 1989 time period. The corresponding provider and user capital and O&M costs are shown in Table 8-9 and 8-10 under the assumptions of 100% and 50% separation assurance device user avionics capital cost allocations to NAT operations, respectively. The COM and ATS facility O&M costs are assumed to be the same as those of the baseline configuration.

8.2.7 Configuration 10. Automatic Dependent Surveillance With Network HF Data Link and Voice

Based on the analysis of operating requirements presented in Section 4, the automatic dependent surveillance with network HF data link system, which includes direct air-ground data link communication between pilot and controller as well as automated ATC data handling, controller displays and associated advanced ATC automation, is another possible means of supporting 30 nmi and 5 min lateral and longitudinal separations provided that MNPS (Improved) is also implemented; one-sigma navigation system accuracy values of 3 nmi and slightly larger (such as 3.65 nmi) were considered by the Aviation Review Committee (ref. 1). The direct air-ground data link communication and the automated data handling, displays and associated advanced automation would provide aircraft surveillance data to enable timely potential conflict intervention and would be used for controller intervention communications. The direct air-ground voice capability would facilitate the handling of emergency and other contingency situations.

The Aviation Review Committee reached a consensus regarding the need for a demonstration that the distribution of along-track and across-track errors would be compatible with an acceptable level of safety for a value of 5 min and 30 nmi respectively, and stated that the MNPS (Improved) criteria should ensure that the main bodies of the lateral navigation performance distributions (i.e., as defined in the MNPS) would not significantly overlap in the new system. As regards the tails of the distributions, the Committee agreed that an automatic dependent surveillance function would allow some detection of large errors such that corrective action could be taken to preclude those deviations from developing to the point of posing a collision risk. The achieved level of detection and correction would have to be demonstrated as limiting the large errors to an acceptable level. Direct controller-pilot communications would allow real time monitoring and intervention as necessary to assist in achieving and maintaining the 5 min along-track minimum (ref. 1).

TABLE 8-9

COST SUMMARY FOR NAT CONFIGURATION 8:
SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.500	0.000	0.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.520	3779.420	3812.940	1982
1983	0.500	0.000	0.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	34.380	3928.870	3963.250	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2676.01	1406.35	4084.36	34.630	4084.360	4118.988	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	23.465	1.112	24.577	2783.44	1453.98	4237.42	35.500	4261.992	4297.488	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	23.465	1.138	24.603	2893.03	1503.22	4396.25	36.370	4420.852	4457.219	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	23.465	1.165	24.630	3006.93	1554.14	4561.07	37.250	4585.695	4622.941	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	1.690	1.193	2.883	3125.31	1606.77	4732.08	38.130	4734.961	4773.090	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	1.690	1.221	2.911	3248.36	1661.19	4909.55	39.020	4912.457	4951.477	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	1.690	1.250	2.940	3366.74	1715.47	5082.21	40.020	5085.145	5125.164	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	1.690	1.279	2.969	3499.08	1773.53	5272.61	40.930	5275.578	5316.508	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	1.690	1.309	2.999	3636.62	1833.56	5470.18	41.940	5473.176	5515.113	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	1.690	1.340	3.030	3779.56	1895.62	5675.18	42.960	5678.207	5721.164	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	1.690	1.372	3.062	3928.13	1959.79	5887.92	43.990	5890.977	5934.965	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	1.690	1.404	3.094	4082.53	2026.12	6108.65	45.020	6111.742	6156.762	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	1.690	1.437	3.127	4217.87	2088.82	6306.69	46.070	6309.813	6355.879	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	1.690	1.470	3.160	4357.70	2153.47	6511.17	47.220	6514.324	6561.543	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	1.690	1.503	3.193	4502.16	2220.11	6722.27	48.380	6725.461	6773.840	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	1.690	1.538	3.228	4651.41	2288.82	6940.23	49.450	6943.453	6992.902	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	1.690	1.573	3.263	4805.61	2359.65	7165.26	50.730	7168.520	7219.246	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	1.690	1.610	3.300	4964.93	2432.68	7397.61	51.910	7400.906	7452.813	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	1.690	1.647	3.337	5129.52	2507.96	7637.48	53.110	7640.813	7693.922	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	1.690	1.684	3.374	5299.55	2585.58	7885.13	54.420	7888.500	7942.918	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	1.690	1.723	3.413	5475.26	2665.60	8140.86	55.730	8144.270	8199.996	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	1.690	1.763	3.453	5656.77	2748.09	8404.86	57.060	8408.309	8465.367	2005

TABLE 8-10
COST SUMMARY FOR NAT CONFIGURATION 9:
SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.500	0.000	0.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.520	3779.420	3812.940	1982
1983	0.500	0.000	0.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	34.360	3928.870	3963.250	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.968	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	11.733	1.112	12.845	2783.44	1453.98	4237.42	35.500	4250.262	4285.758	1985
1986	0.000	0.000	0.000	11.57	24.80	36.37	11.733	1.138	12.871	2893.03	1503.22	4396.25	36.370	4409.117	4445.484	1986
1987	0.000	0.000	0.000	11.85	25.40	37.25	11.733	1.165	12.898	3006.93	1554.14	4561.07	37.250	4573.961	4611.207	1987
1988	0.000	0.000	0.000	12.13	26.00	38.13	0.845	1.193	2.038	3125.31	1606.77	4732.08	38.130	4734.113	4772.242	1988
1989	0.000	0.000	0.000	12.42	26.60	39.02	0.845	1.221	2.066	3248.36	1661.19	4909.55	39.020	4911.609	4950.629	1989
1990	0.000	0.000	0.000	12.72	27.30	40.02	0.845	1.250	2.095	3366.74	1715.47	5082.21	40.020	5084.301	5124.320	1990
1991	0.000	0.000	0.000	13.03	27.90	40.93	0.845	1.279	2.124	3499.08	1773.53	5272.61	40.930	5274.730	5315.660	1991
1992	0.000	0.000	0.000	13.34	28.60	41.94	0.845	1.309	2.154	3636.62	1833.56	5470.18	41.940	5472.332	5514.270	1992
1993	0.000	0.000	0.000	13.66	29.30	42.96	0.845	1.340	2.185	3779.56	1895.62	5675.18	42.960	5677.363	5720.320	1993
1994	0.000	0.000	0.000	13.99	30.00	43.99	0.845	1.372	2.217	3928.13	1959.79	5887.92	43.990	5890.133	5934.121	1994
1995	0.000	0.000	0.000	14.32	30.70	45.02	0.845	1.404	2.249	4082.53	2026.12	6108.65	45.020	6110.895	6155.914	1995
1996	0.000	0.000	0.000	14.67	31.40	46.07	0.845	1.437	2.282	4217.87	2088.82	6306.69	46.070	6308.969	6355.035	1996
1997	0.000	0.000	0.000	15.02	32.20	47.22	0.845	1.470	2.315	4357.70	2153.47	6511.17	47.220	6513.480	6560.699	1997
1998	0.000	0.000	0.000	15.38	33.00	48.38	0.845	1.503	2.348	4502.16	2220.11	6722.27	48.380	6724.617	6772.996	1998
1999	0.000	0.000	0.000	15.75	33.70	49.45	0.845	1.538	2.383	4651.41	2288.82	6940.23	49.450	6942.609	6992.059	1999
2000	0.000	0.000	0.000	16.13	34.60	50.73	0.845	1.573	2.418	4805.61	2359.65	7165.26	50.730	7167.676	7218.402	2000
2001	0.000	0.000	0.000	16.51	35.40	51.91	0.845	1.610	2.455	4964.93	2432.68	7397.61	51.910	7400.063	7451.969	2001
2002	0.000	0.000	0.000	16.91	36.20	53.11	0.845	1.647	2.492	5129.52	2507.96	7637.48	53.110	7639.965	7693.074	2002
2003	0.000	0.000	0.000	17.32	37.10	54.42	0.845	1.684	2.529	5299.55	2585.58	7885.13	54.420	7887.656	7942.074	2003
2004	0.000	0.000	0.000	17.73	38.00	55.73	0.845	1.723	2.568	5475.26	2665.60	8140.86	55.730	8143.426	8199.152	2004
2005	0.000	0.000	0.000	18.16	38.90	57.06	0.845	1.763	2.608	5656.77	2748.09	8404.86	57.060	8407.465	8464.523	2005

The automatic dependent surveillance with network HF data link and voice, MNPS (Improved) and automated ATC data handling, controller displays and associated advanced automation are assumed to be implemented by 1988 with a 2-year operational shake-down and refinement program ending by 1990. Therefore, the baseline separation minima are assumed to be in effect from 1979 through 1989 and the 30 nmi/5 min/2000 ft separations are assumed to be implemented in 1990 and continued through the year 2005. Allowing for the transition required to prepare for the operational shake-down phase, the provider O&M costs associated with the technical improvements are assumed to begin in 1987 and continue through 2005. The provider COM facilities O&M costs are assumed to change from the baseline annual expenses to the lower improvement system expenses in 1990 when the reduced separations are implemented. The provider ATS facilities O&M costs are assumed to be the same as those of the baseline. Provider ATS facility capital costs for automated data handling, displays and associated automation are required, as are capital and O&M costs for the network HF data link and voice system development and implementation. The user capital and O&M costs for avionics improvements are assumed to begin in 1985 to allow for a fully equipped fleet by 1990. The corresponding provider and user capital and O&M costs are shown in Table 8-11.

8.2.8 Configuration 11. Configuration 10 + Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation

The Aviation Review Committee has pointed out that, if a detailed examination of Configuration 10 could not demonstrate that the level of detection of errors would be sufficient to justify the proposed reduction in separation minima, alternative courses of action would be available, including changes in the MNPS and separation minima. However, the Committee also agreed that a configuration--Configuration 11--could be defined as being identical to Configuration 10 except that Configuration 11 would involve the addition of an airborne separation assurance device which could protect against potential collision risk otherwise associated with the undetected large errors. The airborne separation assurance device with the 50% user avionics capital cost allocation to NAT operations was identified by the Committee for further study (ref. 1).

The Configuration 11 provider and user capital and O&M costs shown in Table 8-12 assume that automatic dependent surveillance and airborne separation assurance device operations will commence in 1990 after completion of the appropriate implementation and shakedown programs. The user flight costs shown in Table 8-12 correspond to the continuation of the baseline separation minima through 1989 and the use of the 30 nmi/5 min/2000 ft separations in 1990 through 2005.

8.2.9 Configuraion 12, 13, and 14. Simpl· HF Network HF Data Link and Voice With and Without Separation Minima Reduction and With and Without Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation

TABLE 8-11

COST SUMMARY FOR NAT CONFIGURATION 10:
AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.000	0.000	1.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.280	3640.390	3673.670	1981
1982	1.000	0.000	1.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.020	3779.420	3813.440	1982
1983	7.000	0.000	7.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	40.880	3928.870	3969.750	1983
1984	7.995	0.000	7.995	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	42.625	4084.360	4126.984	1984
1985	7.995	0.200	8.195	11.30	24.20	35.50	19.635	1.112	20.747	2783.44	1453.98	4237.42	43.695	4258.164	4301.855	1985
1986	7.995	0.300	8.295	11.57	24.80	36.37	19.635	1.138	20.773	2893.03	1503.22	4396.25	44.665	4417.020	4461.684	1986
1987	11.495	1.600	13.095	11.85	25.40	37.25	19.635	1.165	20.800	3006.93	1554.14	4561.07	50.345	4581.863	4632.207	1987
1988	0.000	1.600	1.600	12.13	26.00	38.13	1.489	1.193	2.682	3125.31	1606.77	4732.08	39.730	4734.758	4774.484	1988
1989	0.000	1.600	1.600	12.42	26.60	39.02	1.489	1.221	2.710	3248.36	1661.19	4909.55	40.620	4912.254	4952.871	1989
1990	0.000	1.600	1.600	5.34	27.30	32.64	1.489	1.250	2.739	3366.74	1715.47	5082.21	34.240	5084.945	5119.184	1990
1991	0.000	1.600	1.600	5.47	27.90	33.37	1.489	1.279	2.768	3499.08	1773.53	5272.61	34.970	5275.375	5310.344	1991
1992	0.000	1.600	1.600	5.60	28.60	34.20	1.489	1.309	2.798	3636.62	1833.56	5470.18	35.300	5472.977	5508.773	1992
1993	0.000	1.600	1.600	5.74	29.30	35.04	1.489	1.340	2.829	3779.56	1895.62	5675.18	36.640	5678.008	5714.645	1993
1994	0.000	1.600	1.600	5.88	30.00	35.88	1.489	1.372	2.861	3928.13	1959.79	5887.92	37.480	5890.777	5928.254	1994
1995	1.000	1.600	2.600	6.01	30.70	36.71	1.489	1.404	2.893	4082.53	2026.12	6108.65	39.310	6111.539	6150.848	1995
1996	0.000	1.600	1.600	6.16	31.40	37.56	1.489	1.437	2.926	4217.87	2088.82	6306.69	39.160	6309.613	6348.770	1996
1997	0.000	1.600	1.600	6.31	32.20	38.51	1.489	1.470	2.959	4357.70	2153.47	6511.17	40.110	6514.125	6554.234	1997
1998	0.000	1.600	1.600	6.46	33.00	39.46	1.489	1.503	2.992	4502.16	2220.11	6722.27	41.060	6725.258	6766.316	1998
1999	0.000	1.600	1.600	6.62	33.70	40.32	1.489	1.538	3.027	4651.41	2288.82	6940.23	41.920	6943.250	6985.168	1999
2000	1.000	1.600	2.600	6.77	34.60	41.37	1.489	1.573	3.062	4805.61	2359.65	7165.26	43.970	7168.316	7212.285	2000
2001	0.000	1.600	1.600	6.93	35.40	42.33	1.489	1.610	3.099	4964.93	2432.68	7397.61	43.930	7400.707	7444.637	2001
2002	0.000	1.600	1.600	7.10	36.20	43.30	1.489	1.647	3.136	5129.52	2507.96	7637.48	44.900	7640.609	7685.508	2002
2003	0.000	1.600	1.600	7.27	37.10	44.37	1.489	1.684	3.173	5299.55	2585.58	7885.13	45.970	7888.301	7934.270	2003
2004	0.000	1.600	1.600	7.45	38.00	45.45	1.489	1.723	3.212	5475.26	2665.60	8140.86	47.050	8144.070	8191.117	2004
2005	1.000	1.600	2.600	7.63	38.90	46.53	1.489	1.763	3.252	5656.77	2748.09	8404.86	49.130	8408.109	8457.238	2005

TABLE 8-12
COST SUMMARY FOR NAT CONFIGURATION 11:
AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.000	0.000	1.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.280	3640.390	3673.670	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	7.500	0.000	7.500	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	41.380	3928.870	3970.250	1983
1984	7.995	0.000	7.995	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	42.625	4084.360	4126.984	1984
1985	7.995	0.200	8.195	11.30	24.20	35.50	31.368	2.224	33.592	2783.44	1453.98	4237.42	43.695	4271.008	4314.699	1985
1986	7.995	0.300	8.295	11.57	24.80	36.37	31.368	2.276	33.644	2893.03	1503.22	4396.25	44.665	4429.891	4474.555	1986
1987	11.495	1.600	13.095	11.85	25.40	37.25	31.368	2.330	33.698	3006.93	1554.14	4561.07	50.345	4594.762	4645.105	1987
1988	0.000	1.500	1.500	12.13	26.00	38.13	2.334	2.386	4.720	3125.31	1606.77	4732.08	39.730	4736.797	4776.523	1988
1989	0.000	1.600	1.600	12.42	26.60	39.02	2.334	2.442	4.776	3248.36	1661.19	4909.55	40.620	4914.320	4954.938	1989
1990	0.000	1.600	1.600	5.34	27.30	32.64	2.334	2.500	4.834	3366.74	1715.47	5082.21	34.240	5087.039	5121.277	1990
1991	0.000	1.600	1.600	5.47	27.90	33.37	2.334	2.558	4.892	3499.08	1773.53	5272.61	34.970	5277.500	5312.469	1991
1992	0.000	1.600	1.600	5.60	28.60	34.20	2.334	2.618	4.952	3636.62	1833.56	5470.18	35.800	5475.129	5510.926	1992
1993	0.000	1.600	1.600	5.74	29.30	35.04	2.334	2.680	5.014	3779.56	1895.62	5675.18	36.640	5680.191	5716.828	1993
1994	0.000	1.600	1.600	5.88	30.00	35.88	2.334	2.744	5.078	3928.13	1959.79	5887.92	37.480	5892.992	5930.469	1994
1995	1.000	1.600	2.600	6.01	30.70	36.71	2.334	2.808	5.142	4082.53	2026.12	6108.65	39.310	6113.789	6153.098	1995
1996	0.000	1.600	1.600	6.16	31.40	37.56	2.334	2.874	5.208	4217.87	2088.82	6306.69	39.160	6311.895	6351.051	1996
1997	0.000	1.600	1.600	6.31	32.20	38.51	2.334	2.940	5.274	4357.70	2153.47	6511.17	40.110	6516.441	6556.551	1997
1998	0.000	1.600	1.600	6.46	33.00	39.46	2.334	3.006	5.340	4502.16	2220.11	6722.27	41.060	6727.609	6768.668	1998
1999	0.000	1.600	1.600	6.62	33.70	40.32	2.334	3.076	5.410	4651.41	2288.82	6940.23	41.920	6945.633	6987.551	1999
2000	1.000	1.600	2.600	6.77	34.60	41.37	2.334	3.146	5.480	4805.61	2359.65	7165.26	43.970	7170.734	7214.703	2000
2001	0.000	1.600	1.600	6.93	35.40	42.33	2.334	3.220	5.554	4964.93	2432.68	7397.61	43.930	7403.160	7447.090	2001
2002	0.000	1.600	1.600	7.10	36.20	43.30	2.334	3.294	5.628	5129.52	2507.96	7637.48	44.900	7643.102	7688.000	2002
2003	0.000	1.600	1.600	7.27	37.10	44.37	2.334	3.368	5.702	5299.55	2585.58	7885.13	45.970	7890.828	7936.797	2003
2004	0.000	1.600	1.600	7.45	38.00	45.45	2.334	3.446	5.780	5475.26	2665.60	8140.86	47.050	8146.637	8193.684	2004
2005	1.000	1.600	2.600	7.63	38.90	46.53	2.334	3.526	5.860	5656.77	2748.09	8404.86	49.130	8410.719	8459.848	2005

The simple network HF data link and voice operation would provide a means for establishing automatic dependent surveillance by transmitting direct air-ground messages automatically using a less complex network HF operation than that previously addressed by Configuration 10 and employing automated ATC data handling, controller displays, and associated advanced ATC automation. This network data link and voice operation would require fewer COM station HF radio operators than the current HF voice system but would incur capital and O&M costs associated with HF ground and avionics aircraft communication equipment and provider capital costs associated with automated data handling, displays, and automation at the ATS facilities. As directed by the Aviation Review Committee (ref. 1), the simple network HF data link and voice improvement is examined under the following three operating assumptions for Configurations 12, 13 and 14, respectively: (1) without separation minima reductions (i.e., the baseline minima are assumed to apply), and (2) with separation minima reductions to 30 nmi/5 min/2000 ft in 1993 with MNPS (Improved), and (3) identical to (2) except for the addition of the airborne separation assurance device with 50% avionics capital cost allocation.

The Aviation Review Committee agreed that Configurations 12, 13 and 14 were considered viable as relatively early attainable steps toward the attainment of improved ATC with the capability of increased tactial intervention. The Committee stated that Configuration 12 had to be considered a viable improvement option if only for the benefits of improved communications and automatic dependent surveillance, and hence, its potential as compared with HF SSB air-ground voice to detect certain kinds of ATC loop errors and other large errors. It would be necessary that the simple network HF data link system realize: a reliability (in continuous operation) equal to or better than current HF SSB voice communications; a flexibility and redundancy in the communications path equal to or better than the current HF SSB voice communications; a sufficient predictability in its availability to enable alternative procedures to be invoked when necessary; a suitable interface with Extended Range VHF coverage, which would require some study of the issues involved (ref. 1).

The Committee agreed that Configuration 13 extended the advantages of Configuration 12 to reflect a reduction of separation minima to 30nmi/5 min/2000 ft achieved through MNPS (Improved) by 1993. This configuration, building as it did on Configuration 12, was aimed at providing the controller with airborne derived MNPS (Improved) position data. The Committee stated that Configuration 14, with an airborne separation assurance device, would have further protection in those infrequent situations when the device was activated, and the device would provide primary protection against collision if the data link system failed. The Committee noted that any communications improvement providing data link would facilitate direct pilot-controller communications and consequently the more efficient use of staff (ref. 1).

In regard to the simple network HF data link and voice without separation minima reduction of Configuration 12, ground system implementation of the communication and automated ATC data handling, controller displays and associated advanced ATC automation functions is assumed to be completed in 1987. Single HF avionics installation is assumed to occur gradually beginning in 1985, with full fleet equippage occurring in 1991. Partial data link and voice service is assumed to begin in 1987, involving the compatibly equipped aircraft and that part of the ground system that is operational, with full service with all aircraft beginning in 1992. The size of the COM stations radio operator staffs is assumed to decrease linearly during the 1987 through 1991 transition from present system to full simple network HF data link and voice operations. Table 8-13 shows the provider and user capital and O&M cost estimates for Configuration 12.

In regard to the simple network HF data link and voice with separation minima reduction of Configuration 13, the decision to evolve to the 30 nmi lateral and 5 min longitudinal minima is assumed to be made before 1990 and would be based on observations of the performance of Configuration 12. Evolution from Configuration 12 to 13 would require establishment of dual simple network HF avionics and MNPS (Improved). Installation of the second HF avionics units on board all aircraft is assumed to occur during 1990 through 1992. This schedule would enable system performance shake-down and check-out prior to 1993 of the simple network HF data link and voice with MNPS (Improved) and at least single unit avionics equippage for the full fleet and dual unit avionics equippage for part of the fleet. The 30 nmi/5 min/2000 ft separation minima are assumed to begin in 1993. Table 8-14 shows the provider and user capital and O&M cost estimates for Configuration 13.

In regard to the simple network HF data link and voice with separation minima reductions and with the airborne separation assurance device with the 50% avionics capital cost allocation of Configuration 14, the separation assurance device avionics are assumed to be installed during 1988 through 1990. This installation program would be in addition to the avionics required for Configuration 12 and 13, and would allow for a 2-year shakedown during 1991 and 1992 of operations with the airborne separation assurance device. The 30 nmi/5 min/2000 ft separation minima are assumed to begin in 1993. Table 8-15 shows the provider and user capital and O&M cost estimates for Configuration 14.

8.2.10 Configurations 15 and 16. Automatic Dependent Surveillance With Satellite Data Link and Voice With and Without Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation

The automatic dependent surveillance with satellite data link and voice, in conjunction with MNPS (Improved), and the direct air-ground communications and automated ATC data handling, controller displays and associated advanced ATC automation, also is a possible means of implementing 30 nmi lateral and 5 min longitudinal separations. The discussion presented in the preceding paragraphs for the HF system relevant to

TABLE 8-13
COST SUMMARY FOR NAT CONFIGURATION 12: SIMPLE NETWORK HF DATA LINK AND VOICE WITHOUT SEPARATION MINIMA REDUCTION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.667	0.000	0.667	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.947	3640.390	3673.337	1981
1982	0.667	0.000	0.667	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.687	3779.420	3813.107	1982
1983	5.667	0.000	5.667	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	39.547	3928.870	3968.417	1983
1984	6.507	0.000	6.507	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.137	4084.360	4125.496	1984
1985	6.507	0.000	6.507	11.30	24.20	35.50	4.636	1.112	5.748	2783.44	1453.98	4237.42	42.007	4243.164	4285.168	1985
1986	6.507	0.740	7.247	11.57	24.80	36.37	4.636	1.138	5.774	2893.03	1503.22	4396.25	43.617	4402.023	4445.637	1986
1987	9.707	0.790	10.497	10.58	25.40	35.98	4.636	1.165	5.801	3006.93	1554.14	4561.07	46.477	4566.867	4613.344	1987
1988	0.000	0.840	0.840	9.58	26.00	35.58	4.636	1.193	5.829	3125.31	1606.77	4732.08	36.420	4737.906	4774.324	1988
1989	0.000	0.840	0.840	8.58	26.60	35.18	4.636	1.221	5.857	3248.36	1661.19	4909.55	36.020	4915.402	4951.422	1989
1990	0.000	0.840	0.840	7.59	27.30	34.89	4.636	1.250	5.886	3376.25	1717.45	5093.70	35.730	5099.582	5135.309	1990
1991	0.000	0.840	0.840	6.60	27.90	34.50	4.636	1.279	5.915	3509.17	1775.62	5284.79	35.340	5290.703	5326.043	1991
1992	0.000	0.840	0.840	5.60	28.60	34.20	0.744	1.309	2.053	3647.33	1835.76	5483.09	35.040	5485.141	5520.180	1992
1993	0.000	0.840	0.840	5.74	29.30	35.04	0.744	1.340	2.084	3790.92	1897.93	5688.85	35.880	5690.930	5726.809	1993
1994	0.000	0.840	0.840	5.88	30.00	35.88	0.744	1.372	2.116	3940.17	1962.21	5902.38	36.720	5904.492	5941.211	1994
1995	1.000	0.840	1.840	6.01	30.70	36.71	0.744	1.404	2.148	4095.30	2028.67	6123.97	38.550	6126.113	6164.660	1995
1996	0.000	0.840	0.840	6.16	31.40	37.56	0.744	1.437	2.181	4231.19	2091.44	6322.63	38.400	6324.809	6363.207	1996
1997	0.000	0.840	0.840	6.31	32.20	38.51	0.744	1.470	2.214	4371.58	2156.15	6527.73	39.350	6529.938	6569.285	1997
1998	0.000	0.840	0.840	6.46	33.00	39.46	0.744	1.503	2.247	4516.64	2222.86	6739.50	40.300	6741.746	6782.043	1998
1999	0.000	0.840	0.840	6.62	33.70	40.32	0.744	1.538	2.282	4666.51	2291.64	6958.15	41.160	6960.430	7001.586	1999
2000	1.000	0.840	1.840	6.77	34.60	41.37	0.744	1.573	2.317	4821.35	2362.55	7183.90	43.210	7186.215	7229.422	2000
2001	0.000	0.840	0.840	6.93	35.40	42.33	0.744	1.610	2.354	4981.33	2435.64	7416.96	43.170	7419.316	7462.484	2001
2002	0.000	0.840	0.840	7.10	36.20	43.30	0.744	1.647	2.391	5146.62	2511.01	7657.63	44.140	7660.020	7704.156	2002
2003	0.000	0.840	0.840	7.27	37.10	44.37	0.744	1.684	2.428	5317.39	2588.70	7906.09	45.210	7908.516	7953.723	2003
2004	0.000	0.840	0.840	7.45	38.00	45.45	0.744	1.723	2.467	5493.83	2668.80	8162.63	46.290	8165.090	8211.379	2004
2005	1.000	0.840	1.840	7.63	38.90	46.53	0.744	1.763	2.507	5676.12	2751.37	8427.49	48.370	8429.992	8478.359	2005

TABLE 8-14
COST SUMMARY FOR NAT CONFIGURATION 13: SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.667	0.000	0.667	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.947	3640.390	3673.337	1981
1982	0.667	0.000	0.667	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.687	3779.420	3813.107	1982
1983	5.667	0.000	5.667	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	39.547	3928.870	3968.417	1983
1984	6.507	0.000	6.507	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.137	4084.360	4125.496	1984
1985	6.507	0.000	6.507	11.30	24.20	35.50	4.636	1.112	5.748	2783.44	1453.98	4237.42	42.007	4243.164	4285.168	1985
1986	6.507	0.740	7.247	11.57	24.80	36.37	4.636	1.138	5.774	2893.03	1503.22	4396.25	43.617	4402.023	4445.637	1986
1987	9.707	0.790	10.497	10.58	25.40	35.98	4.636	1.165	5.801	3006.93	1554.14	4561.07	46.477	4566.867	4613.344	1987
1988	0.000	0.840	0.840	9.58	26.00	35.58	4.636	1.193	5.829	3125.31	1606.77	4732.08	36.420	4737.906	4774.324	1988
1989	0.000	0.840	0.840	8.58	26.60	35.18	4.636	1.221	5.857	3248.36	1661.19	4909.55	36.020	4915.402	4951.422	1989
1990	0.000	0.840	0.840	7.59	27.30	34.89	9.272	1.250	10.522	3376.25	1717.45	5093.70	35.730	5104.219	5139.945	1990
1991	0.000	0.840	0.840	6.60	27.90	34.50	20.860	1.279	22.139	3509.17	1775.62	5284.79	35.340	5306.926	5342.266	1991
1992	0.000	0.840	0.840	5.60	28.60	34.20	13.077	1.309	14.386	3647.33	1835.76	5483.09	35.040	5497.473	5532.512	1992
1993	0.000	0.840	0.840	5.74	29.30	35.04	1.489	1.340	2.829	3779.56	1895.62	5675.18	35.880	5678.008	5713.887	1993
1994	0.000	0.840	0.840	5.88	30.00	35.88	1.489	1.372	2.861	3928.13	1959.79	5887.92	36.720	5890.777	5927.496	1994
1995	1.000	0.840	1.840	6.01	30.70	36.71	1.489	1.404	2.893	4082.53	2026.12	6108.65	38.550	6111.539	6150.086	1995
1996	0.000	0.840	0.840	6.16	31.40	37.56	1.489	1.437	2.926	4217.87	2088.82	6306.69	38.400	6309.613	6348.012	1996
1997	0.000	0.840	0.840	6.31	32.20	38.51	1.489	1.470	2.959	4357.70	2153.47	6511.17	39.350	6514.125	6553.473	1997
1998	0.000	0.840	0.840	6.46	33.00	39.46	1.489	1.503	2.992	4502.16	2220.11	6722.27	40.300	6725.258	6765.555	1998
1999	0.000	0.840	0.840	6.62	33.70	40.32	1.489	1.538	3.027	4651.41	2288.82	6940.23	41.160	6943.250	6984.406	1999
2000	1.000	0.840	1.840	6.77	34.60	41.37	1.489	1.573	3.062	4805.61	2359.65	7165.26	43.210	7168.316	7211.523	2000
2001	0.000	0.840	0.840	6.93	35.40	42.33	1.489	1.610	3.099	4964.93	2432.68	7397.61	43.170	7400.707	7443.875	2001
2002	0.000	0.840	0.840	7.10	36.20	43.30	1.489	1.647	3.136	5129.52	2507.96	7637.48	44.140	7640.609	7684.746	2002
2003	0.000	0.840	0.840	7.27	37.10	44.37	1.489	1.684	3.173	5299.55	2585.58	7885.13	45.210	7888.301	7933.508	2003
2004	0.000	0.840	0.840	7.45	38.00	45.45	1.489	1.723	3.212	5475.26	2665.60	8140.86	46.290	8144.070	8190.359	2004
2005	1.000	0.840	1.840	7.63	38.90	46.53	1.489	1.763	3.252	5656.77	2748.09	8404.86	48.370	8408.109	8456.477	2005

TABLE 8-15
COST SUMMARY FOR NAT CONFIGURATION 14:
SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION
AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.667	0.000	0.667	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.947	3640.390	3673.337	1981
1982	1.167	0.000	1.167	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.187	3779.420	3813.607	1982
1983	6.167	0.000	6.167	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	40.047	3928.870	3968.917	1983
1984	6.507	0.000	6.507	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.137	4084.360	4125.496	1984
1985	6.507	0.000	6.507	11.30	24.20	35.50	4.636	1.112	5.748	2783.44	1453.98	4237.42	42.007	4243.164	4285.168	1985
1986	6.507	0.740	7.247	11.57	24.80	36.37	4.636	1.138	5.774	2893.03	1503.22	4396.25	43.617	4402.023	4445.637	1986
1987	9.707	0.790	10.497	10.58	25.40	35.98	4.636	1.165	5.801	3006.93	1554.14	4561.07	46.477	4566.867	4613.344	1987
1988	0.000	0.840	0.840	9.58	26.00	35.58	17.287	2.386	19.673	3125.31	1606.77	4732.08	36.420	475[illegible].750	4788.168	1988
1989	0.000	0.840	0.840	8.58	26.60	35.18	29.939	2.442	32.381	3248.36	1661.19	4909.55	36.020	4941.926	4977.945	1989
1990	0.000	0.840	0.840	7.59	27.30	34.89	21.923	2.500	24.423	3376.25	1717.45	5093.70	35.730	5118.121	5153.848	1990
1991	0.000	0.840	0.840	6.60	27.90	34.50	21.705	2.558	24.263	3509.17	1775.62	5284.79	35.340	5309.051	5344.391	1991
1992	0.000	0.840	0.840	5.60	28.60	34.20	13.922	2.618	16.540	3647.33	1835.76	5483.09	35.040	5499.629	5534.668	1992
1993	0.000	0.840	0.840	5.74	29.30	35.04	2.334	2.680	5.014	3779.56	1895.62	5675.18	35.880	5680.191	5716.070	1993
1994	0.000	0.840	0.840	5.88	30.00	35.88	2.334	2.744	5.078	3928.13	1959.79	5887.92	36.720	5892.992	5929.711	1994
1995	1.000	0.840	1.840	6.01	30.70	36.71	2.334	2.808	5.142	4082.53	2026.12	6108.65	38.550	6113.789	6152.336	1995
1996	0.000	0.840	0.840	6.16	31.40	37.56	2.334	2.874	5.208	4217.87	2088.82	6306.69	38.400	6311.895	6350.293	1996
1997	0.000	0.840	0.840	6.31	32.20	38.51	2.334	2.940	5.274	4357.70	2153.47	6511.17	39.350	6516.441	6555.789	1997
1998	0.000	0.840	0.840	6.46	33.00	39.46	2.334	3.006	5.340	4502.16	2220.11	6722.27	40.300	6727.609	6767.906	1998
1999	0.000	0.840	0.840	6.62	33.70	40.32	2.334	3.076	5.410	4651.41	2288.82	6940.23	41.160	6945.633	6986.789	1999
2000	1.000	0.840	1.840	6.77	34.60	41.37	2.334	3.146	5.480	4805.61	2359.65	7165.26	43.210	7170.734	7213.941	2000
2001	0.000	0.840	0.840	6.93	35.40	42.33	2.334	3.220	5.554	4964.93	2432.68	7397.61	43.170	7403.160	7446.328	2001
2002	0.000	0.840	0.840	7.10	36.20	43.30	2.334	3.294	5.628	5129.52	2507.96	7637.48	44.140	7643.102	7687.238	2002
2003	0.000	0.840	0.840	7.27	37.10	44.37	2.334	3.368	5.702	5299.55	2585.58	7885.13	45.210	7890.828	7936.035	2003
2004	0.000	0.840	0.840	7.45	38.00	45.45	2.334	3.446	5.780	5475.26	2665.60	8140.86	46.290	8146.637	8192.926	2004
2005	1.000	0.840	1.840	7.63	38.90	46.53	2.334	3.526	5.860	5656.77	2748.09	8404.86	48.370	8410.719	8459.086	2005

operations with and without the airborne separation assurance device also apply to these configurations. A 2-year shake-down is assumed in 1988 and 1989 with two satellites (one a back-up) in orbit and a third (spare) satellite on the ground. The 30 nmi/5 min/2000 ft separations are assumed to be implemented in 1990 and thereafter. The baseline operation is assumed to be in effect during the 1979 through 1989 time period. The corresponding provider and user O&M costs are shown in Table 8-16, for Configuration 15 (i.e.. without the airborne separation assurance device) and in Table 8-17 for Configuration 16 (i.e., with the airborne separation assurance device with the 50% avionics capital cost allocation to NAT operations).

8.2.11 Configurations 17 and 18. Automatic Dependent Surveillance With Satellite Data Link Only With and Without Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation

The fundamental automatic dependent surveillance and direct pilot-controller communication might be achieved by a satellite digital data link without voice communication capability as is assumed in Configuration 17 which is without the airborne separation assurance device. The direct air-ground data link-only communications operation would provide the basic aircraft position data necessary to support establishment of 30 nmi lateral and 5 min longitudinal separation minima in 1990 in conjunction with MNPS (Improved). This configuration would follow the same operational concepts and implementation programs defined for the automatic dependent surveillance with satellite data link and voice (i.e., Configuration 15) except that capital and O&M costs would be less because satellite voice communication facilities are not provided. The Configuration 17 cost estimates are shown in Table 8-18.

The Aviation Review Committee determined that a configuration should be evaluated that is identical to Configuraion 17 but with the addition of an airborne separation assurance device with 50% avionics capital cost allocation to NAT operations (ref. 1). The resulting Configuration 18 would provide for the case that the level of detection of errors of Configuration 17 would not be sufficient to justify the proposed reduction in separation minima. The Configuration 18 cost estimates are shown in Table 8-19.

The Committee noted that the validity of Configurations 17 and 18 depended critically on the acceptability of the postulated data link only satellite system. The Committee could not resolve this issue, but there was no enthusiasm for the prospect of abandoning the voice facility, which would be provided through the residual HF capability (ref. 1).

TABLE 8-16
COST SUMMARY FOR NAT CONFIGURATION 15:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	7.533	0.000	7.533	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	41.413	3928.870	3970.283	1983
1984	7.533	0.000	7.533	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	42.163	4084.360	4126.520	1984
1985	8.511	0.000	8.511	11.30	24.20	35.50	23.380	1.112	24.492	2783.44	1453.98	4237.42	44.011	4261.906	4305.919	1985
1986	14.678	0.100	14.778	11.57	24.80	36.37	23.380	1.138	24.518	2893.03	1503.22	4396.25	51.[illegible]48	4420.766	4471.910	1986
1987	8.978	0.200	9.178	11.85	25.40	37.25	23.380	1.165	24.545	3006.93	1554.14	4561.07	46.428	4585.609	4632.035	1987
1988	6.678	0.650	7.328	12.13	26.00	38.13	1.731	1.193	2.924	3125.31	1606.77	4732.08	45.458	4735.000	4780.457	1988
1989	0.000	0.650	0.650	12.42	26.60	39.02	1.731	1.221	2.952	3248.36	1661.19	4909.55	39.670	4912.496	4952.164	1989
1990	0.000	0.650	0.650	4.20	27.30	31.50	1.731	1.250	2.981	3366.76	1715.47	5082.21	32.150	5085.188	5117.336	1990
1991	0.000	0.650	0.650	4.30	27.90	32.20	1.731	1.279	3.010	3499.08	1773.53	5272.61	32.850	5275.617	5308.465	1991
1992	0.000	0.650	0.650	4.40	28.60	33.00	1.731	1.309	3.040	3636.62	1833.56	5470.18	33.650	5473.219	5506.867	1992
1993	5.700	0.650	6.350	4.51	29.30	33.81	1.731	1.340	3.071	3779.56	1895.62	5675.18	40.160	5678.250	5718.406	1993
1994	0.000	0.650	0.650	4.62	30.00	34.62	1.731	1.372	3.103	3928.13	1959.79	5887.92	35.270	5891.020	5926.289	1994
1995	6.700	0.650	7.350	4.73	30.70	35.43	1.731	1.404	3.135	4082.53	2026.12	6108.65	42.780	6111.781	6154.559	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.731	1.437	3.168	4217.87	2088.82	6306.69	36.890	6309.855	6346.742	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.731	1.470	3.201	4357.70	2153.47	6511.17	37.810	6514.367	6552.176	1997
1998	0.000	0.650	0.650	5.08	33.00	38.08	1.731	1.503	3.234	4502.16	2220.11	6722.27	38.730	6725.500	6764.227	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.731	1.538	3.269	4651.41	2288.82	6940.23	39.550	6943.492	6983.039	1999
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.731	1.573	3.304	4805.61	2359.65	7165.26	47.270	7168.559	7215.828	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.731	1.610	3.341	4964.93	2432.68	7397.61	41.500	7400.949	7442.445	2001
2002	5.700	0.650	6.350	5.58	36.20	41.78	1.731	1.647	3.378	5129.52	2507.96	7637.48	48.130	7640.852	7688.980	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.731	1.684	3.415	5299.55	2585.58	7885.13	43.470	7888.543	7932.012	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.731	1.723	3.454	5475.26	2665.60	8140.86	44.500	8144.313	8188.809	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.731	1.763	3.494	5656.77	2748.09	8404.86	46.540	8408.352	8454.891	2005

TABLE 8-17
COST SUMMARY FOR NAT CONFIGURATION 16:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE AND
SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	2.000	0.000	2.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	35.020	3779.420	3814.440	1982
1983	8.033	0.000	8.033	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	41.913	3928.870	3970.783	1983
1984	7.533	0.000	7.533	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	42.163	4084.360	4126.520	1984
1985	8.511	0.000	8.511	11.30	24.20	35.50	35.113	2.224	37.337	2783.44	1453.98	4237.42	44.011	4274.754	4318.762	1985
1986	14.678	0.100	14.778	11.57	24.80	36.37	35.113	2.276	37.389	2893.03	1503.22	4396.25	51.148	4433.637	4484.781	1986
1987	8.978	0.200	9.178	11.85	25.40	37.25	35.113	2.330	37.443	3006.93	1554.14	4561.07	46.428	4598.508	4644.934	1987
1988	6.678	0.650	7.328	12.13	26.00	38.13	2.576	2.386	4.962	3125.31	1606.77	4732.08	45.458	4737.039	4782.496	1988
1989	0.000	0.650	0.650	12.42	26.60	39.02	2.576	2.442	5.018	3248.36	1661.19	4909.55	39.670	4914.563	4954.230	1989
1990	0.000	0.650	0.650	4.20	27.30	31.50	2.576	2.500	5.076	3366.74	1715.47	5082.21	32.150	5087.281	5119.430	1990
1991	0.000	0.650	0.650	4.30	27.90	32.20	2.576	2.558	5.134	3499.08	1773.53	5272.61	32.850	5277.742	5310.590	1991
1992	0.000	0.650	0.650	4.40	28.60	33.00	2.576	2.618	5.194	3636.62	1833.56	5470.18	33.650	5475.371	5509.020	1992
1993	5.700	0.650	6.350	4.51	29.30	33.81	2.576	2.680	5.256	3779.56	1895.62	5675.18	40.160	5680.434	5720.590	1993
1994	0.000	0.650	0.650	4.62	30.00	34.62	2.576	2.744	5.320	3928.13	1959.79	5887.92	35.270	5893.234	5928.504	1994
1995	6.700	0.650	7.350	4.73	30.70	35.43	2.576	2.808	5.384	4082.53	2026.12	6108.65	42.780	6114.031	6156.809	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	2.576	2.874	5.450	4217.87	2088.82	6306.69	36.890	6312.137	6349.023	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	2.576	2.940	5.516	4357.70	2153.47	6511.17	37.810	6516.684	6554.492	1997
1998	0.000	0.650	0.650	5.08	33.00	38.08	2.576	3.006	5.582	4502.16	2220.11	6722.27	38.730	6727.848	6766.574	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	2.576	3.076	5.652	4651.41	2288.82	6940.23	39.550	6945.875	6985.422	1999
2000	6.700	0.650	7.350	5.32	34.60	39.92	2.576	3.146	5.722	4805.61	2359.65	7165.26	47.270	7170.977	7218.246	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	2.576	3.220	5.796	4964.93	2432.68	7397.61	41.500	7403.402	7444.898	2001
2002	5.700	0.650	6.350	5.58	36.20	41.78	2.576	3.294	5.870	5129.52	2507.96	7637.48	48.130	7643.344	7691.473	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	2.576	3.368	5.944	5299.55	2585.58	7885.13	43.470	7891.070	7934.539	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	2.576	3.446	6.022	5475.26	2665.60	8140.86	44.500	8146.879	8191.375	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	2.576	3.526	6.102	5656.77	2748.09	8404.86	46.540	8410.961	8457.500	2005

TABLE 8-18
COST SUMMARY FOR NAT CONFIGURATION 17:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE, DATA LINK ONLY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982
1983	6.490	0.000	6.490	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	40.370	3928.870	3969.240	1983
1984	6.490	0.000	6.490	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.120	4084.360	4125.477	1984
1985	7.468	0.000	7.468	11.30	24.20	35.50	16.074	1.112	17.186	2783.44	1453.98	4237.42	42.968	4254.602	4297.566	1985
1986	10.728	0.100	10.828	11.57	24.80	36.37	16.074	1.138	17.212	2893.03	1503.22	4396.25	47.198	4413.461	4460.656	1986
1987	8.978	0.200	9.178	11.85	25.40	37.25	16.074	1.165	17.239	3006.93	1554.14	4561.07	46.428	4578.305	4624.730	1987
1988	4.328	0.650	4.978	12.13	26.00	38.13	1.177	1.193	2.370	3125.31	1606.77	4732.08	43.108	4734.445	4777.551	1988
1989	0.000	0.650	0.650	12.42	26.60	39.02	1.177	1.221	2.398	3248.36	1661.19	4909.55	39.670	4911.941	4951.609	1989
1990	0.000	0.650	0.650	4.20	27.30	31.50	1.177	1.250	2.427	3366.74	1715.47	5082.21	32.150	5084.633	5116.781	1990
1991	0.000	0.650	0.650	4.30	27.90	32.20	1.177	1.279	2.456	3499.08	1773.53	5272.61	32.850	5275.063	5307.910	1991
1992	0.000	0.650	0.650	4.40	28.60	33.00	1.177	1.309	2.486	3636.62	1833.56	5470.18	33.650	5472.664	5506.313	1992
1993	3.350	0.650	4.000	4.51	29.30	33.81	1.177	1.340	2.517	3779.56	1895.62	5675.18	37.810	5677.695	5715.504	1993
1994	0.000	0.650	0.650	4.62	30.00	34.62	1.177	1.372	2.549	3928.13	1959.79	5887.92	35.270	5890.465	5925.734	1994
1995	4.350	0.650	5.000	4.73	30.70	35.43	1.177	1.404	2.581	4082.53	2026.12	6108.65	40.430	6111.227	6151.656	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.177	1.437	2.614	4217.87	2088.82	6306.69	36.890	6309.301	6346.188	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.177	1.470	2.647	4357.70	2153.47	6511.17	37.810	6513.813	6551.621	1997
1998	0.000	0.650	0.650	5.08	33.00	38.08	1.177	1.503	2.680	4502.16	2220.11	6722.27	38.730	6724.949	6763.676	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.177	1.538	2.715	4651.41	2288.82	6940.23	39.550	6942.941	6982.488	1999
2000	4.350	0.650	5.000	5.32	34.60	39.92	1.177	1.573	2.750	4805.61	2359.65	7165.26	44.920	7168.008	7212.926	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.177	1.610	2.787	4964.93	2432.68	7397.61	41.500	7400.395	7441.891	2001
2002	3.350	0.650	4.000	5.58	36.20	41.78	1.177	1.647	2.824	5129.52	2507.96	7637.48	45.780	7640.297	7686.074	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.177	1.684	2.861	5299.55	2585.58	7885.13	43.470	7887.988	7931.457	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.177	1.723	2.900	5475.26	2665.60	8140.86	44.500	8143.758	8188.254	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.177	1.763	2.940	5656.77	2748.09	8404.86	46.540	8407.797	8454.336	2005

TABLE 8-19

COST SUMMARY FOR NAT CONFIGURATION 18:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK ONLY AND
SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981
1982	2.000	0.000	2.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	35.020	3779.420	3814.440	1982
1983	6.990	0.000	6.990	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	40.870	3928.870	3969.740	1983
1984	6.490	0.000	6.490	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.120	4084.360	4125.477	1984
1985	7.468	0.000	7.468	11.30	24.20	35.50	27.807	2.224	30.031	2783.44	1453.98	4237.42	42.968	4267.445	4310.410	1985
1986	10.728	0.100	10.828	11.57	24.80	36.37	27.807	2.276	30.083	2893.03	1503.22	4396.25	47.198	4426.332	4473.527	1986
1987	8.978	0.200	9.178	11.85	25.40	37.25	27.807	2.330	30.137	3006.93	1554.14	4561.07	46.428	4591.203	4637.629	1987
1988	4.328	0.650	4.978	12.13	26.00	38.13	2.022	2.386	4.408	3125.31	1606.77	4732.08	43.108	4736.484	4779.590	1988
1989	0.000	0.650	0.650	12.42	26.60	39.02	2.022	2.442	4.464	3248.36	1661.19	4909.55	39.670	4914.008	4953.676	1989
1990	0.000	0.650	0.650	4.20	27.30	31.50	2.022	2.500	4.522	3366.74	1715.47	5082.21	32.150	5086.727	5118.875	1990
1991	0.000	0.650	0.650	4.30	27.90	32.20	2.022	2.558	4.580	3499.08	1773.53	5272.61	32.850	5277.188	5310.035	1991
1992	0.000	0.650	0.650	4.40	28.60	33.00	2.022	2.618	4.640	3636.62	1833.56	5470.18	33.650	5474.816	5508.465	1992
1993	3.350	0.650	4.000	4.51	29.30	33.81	2.022	2.680	4.702	3779.56	1895.62	5675.18	37.810	5679.879	5717.688	1993
1994	0.000	0.650	0.650	4.62	30.00	34.62	2.022	2.744	4.766	3928.13	1959.79	5887.92	35.270	5892.684	5927.953	1994
1995	4.350	0.650	5.000	4.73	30.70	35.43	2.022	2.808	4.830	4082.53	2026.12	6108.65	40.430	6113.477	6153.906	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	2.022	2.874	4.896	4217.87	2088.82	6306.69	36.890	6311.582	6348.469	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	2.022	2.940	4.962	4357.70	2153.47	6511.17	37.810	6516.129	6553.938	1997
1998	0.000	0.650	0.650	5.08	33.00	38.08	2.022	3.006	5.028	4502.16	2220.11	6722.27	38.730	6727.297	6766.023	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	2.022	3.076	5.098	4651.41	2288.82	6940.23	39.550	6945.324	6984.871	1999
2000	4.350	0.650	5.000	5.32	34.60	39.92	2.022	3.146	5.168	4805.61	2359.65	7165.26	44.920	7170.426	7215.344	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	2.022	3.220	5.242	4964.93	2432.68	7397.61	41.500	7402.848	7444.344	2001
2002	3.350	0.650	4.000	5.58	36.20	41.78	2.022	3.294	5.316	5129.52	2507.96	7637.48	45.780	7642.789	7688.566	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	2.022	3.368	5.390	5299.55	2585.58	7885.13	43.470	7890.516	7933.984	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	2.022	3.446	5.468	5475.26	2665.60	8140.86	44.500	8146.324	8190.820	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	2.022	3.526	5.548	5656.77	2748.09	8404.86	46.540	8410.406	8456.945	2005

8.2.12 Configuration 19. Cooperative Independent Surveillance With Multiple Satellite Data Link and Voice

Establishment of 15 nmi lateral and 2 min longitudinal separation minima, as discussed in Section 4, requires high air-ground data flow rates and aircraft position monitoring data fidelity such as provided by the independent cooperative surveillance with multiple satellite technology, the associated direct air-ground data link and voice communications, and automated ATC data handling, controller displays and associated advanced automation. The reduced minima would require the implementation of advanced MNPS (i.e., more stringent than improved MNPS) to provide the navigation accuracies necessary to limit controller potential conflict to a reasonable rate of occurrence. The application of 15 nmi and 2 min separation minima are expected to require an MNPS (Advanced) standard, which specifies a one sigma navigation accuracy of about 1.5 nmi. This level of navigation accuracy likely would not be achieved by near-term refinements to the current generation of avionics equipment, in which case advanced avionics would be required. The detailed analysis of design alternatives and costs for advanced navigation is not within the scope of this study, and therefore component cost estimates for such technology have not been obtained (although estimated rough overall costs are provided in Section 9 of this report). However, if advanced navigation systems are provided as part of future domestic ATS system development, the costs of advanced avionics for aircraft flying in the NAT may be assumed to be allocated all or in part to domestic requirements. Also, advanced navigation systems might be introduced as part of the normal equipment replacement cycle.

The development and operational implementation of advanced avionics and the associated MNPS (Advanced) standard is assumed to be possible in 1995, and, for the purposes of this study, the 15 nmi/2 min/2000 ft separations are assumed to be effected in 1995 and not possible earlier. This implementation schedule allows for a 2-year shake-down phase in 1993 and 1994 with three satellites (one a back-up) in orbit and a fourth (spare) satellite on the ground. The baseline separation minima are assumed to be in effect from 1979 through 1994 and the 15 nmi/2 min/2000 ft separation minima are assumed to be applied from 1995 through 2005. The provider O&M costs associated with the improved technology are assumed to be incurred beginning in 1993 with the baseline COM and ATS O&M costs remaining in effect until 1995, at which time the COM facilities O&M annual costs are lowered to reflect improvement system operations. The provider ATS facilities O&M costs are assumed to be the same as those of the baseline, and provider ATS facility outlays for automated data handling, displays and associated automation are included as capital costs. These capital costs are in addition to those provider capital costs required for the improvement system development and implementation. The user capital and O&M costs for avionics associated with communication system improvements are assumed to start in 1990 to allow for a fully equipped fleet by 1995. The corresponding provider and user O&M costs are shown in Table 8-20.

TABLE 8-20
COST SUMMARY FOR NAT CONFIGURATION 19:
COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	[illegible]	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983
1934	0.000	0.000	0.000	11.03	23.60	34.63	0.000	[illegible]	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.980	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	[illegible]	0.000	2783.44	1453.98	4237.42	35.500	4237.418	4272.914	1985
1986	1.500	0.000	1.500	11.57	24.80	36.37	0.000	0.000	0.000	2893.03	1503.22	4396.25	37.870	4396.250	4434.117	1986
1987	1.500	0.000	1.500	11.85	25.40	37.25	0.000	0.000	0.000	3006.93	1554.14	4561.07	38.750	4561.066	4599.813	1987
1988	7.533	0.000	7.533	12.13	26.00	38.13	0.000	0.000	0.000	3125.31	1606.77	4732.08	45.663	4732.078	4777.738	1988
1989	7.533	0.000	7.533	12.42	26.60	39.02	0.000	0.000	0.000	3248.36	1661.19	4909.55	46.553	4909.547	4956.098	1989
1990	9.011	0.000	9.011	12.72	27.30	40.02	28.928	1.250	30.178	3376.25	1717.45	5093.70	49.031	5123.875	5172.902	1990
1991	20.678	0.100	20.778	13.03	27.90	40.93	28.928	1.279	30.207	3509.17	1775.62	5284.79	61.708	5314.992	5376.699	1991
1992	10.478	0.200	10.678	13.34	28.60	41.94	28.928	1.309	30.237	3647.33	1835.76	5483.09	52.618	5513.324	5565.941	1992
1993	7.178	0.650	7.828	13.66	29.30	42.96	1.904	1.340	3.244	3790.92	1897.93	5688.85	50.788	5692.090	5742.875	1993
1994	0.000	0.650	0.650	13.99	30.00	43.99	1.904	1.372	3.276	3940.17	1962.21	5902.38	44.640	5905.652	5950.289	1994
1995	0.000	0.650	0.650	4.73	30.70	35.43	1.904	1.404	3.308	4073.61	2025.31	6098.92	36.080	6102.223	6138.301	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.904	1.437	3.341	4208.31	2087.97	6296.28	36.890	6299.617	6336.504	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.904	1.470	3.374	4347.47	2152.56	6500.03	37.810	6503.398	6541.207	1997
1998	11.400	0.650	12.050	5.08	33.00	38.08	1.904	1.503	3.407	4491.22	2219.16	6710.38	50.130	6713.781	6763.910	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.904	1.538	3.442	4639.73	2287.81	6927.54	39.550	6930.980	6970.527	1999
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.904	1.573	3.477	4793.16	2358.59	7151.75	47.270	7155.227	7202.496	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.904	1.610	3.514	4951.65	2431.56	7383.21	41.500	7386.719	7428.215	2001
2002	0.000	0.650	0.650	5.58	36.20	41.78	1.904	1.647	3.551	5115.39	2506.78	7622.17	42.430	7625.719	7668.148	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.904	1.684	3.588	5284.54	2584.33	7868.87	43.470	7872.453	7915.922	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.904	1.723	3.627	5459.28	2664.28	8123.56	44.500	8127.184	8171.680	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.904	1.763	3.667	5639.80	2746.71	8386.51	46.540	8390.172	8436.711	2005

In regard to the cost estimates for Configuration 19, the Aviation Review Committee observed that certain expenditures may be underestimated because: the MNPS (Advanced) might prove costly in terms of aircraft equipment; the provider cost estimates were based on satellite sharing (as calculated in Section 5) whereas dedicated satellites might be necessary and would be significantly more expensive; there might be cost problems with aircraft antennas because of a need to transmit simultaneously to two satellites; and, to give full cover near to the Poles and to achieve satisfactory position-fixing accuracy near to the equator, a costly combination of geo-stationary and polar-orbiting satellites would be necessary and the operating and maintenance costs of such an arrangement would require study (ref. 1).

With these and other considerations in mind, the Committee recognized that, for these configurations, application must be considered on a world-wide basis. The advantages of such a more general application were that: it would help to resolve the transition problems at the boundaries between Oceanic and Domestic areas, and at the NAT/CAR, NAT/South America (SAM) and similar boundaries; it would provide a means of eliminating other deficiencies which currently existed in many ICAO Regions of the world; it would enhance safety because its "independence" would uniquely help to eliminate some otherwise undetectable aircraft position errors; even for areas where radar coverage already existed it might eventually provide a more cost effective means of surveillance; it would reduce the cost impact of providing dedicated satellites since their common coverage area could be shared between a number of discrete regions; and it would provide a means of monitoring airspace system performance whereby compliance with separaton minima could be confirmed (ref. 1).

8.2.13 Configuration 20. Configuration 19 + Clearance Control Procedures Permitting Exploitation of Free Flight in the Vertical Plane

The Aviation Review Committee invited the UK to assess and introduce a configuration that exploited free flight in the vertical plane based on the operational capabilities afforded by Configuration 19 (ref. 1). The UK response, which describes Configuration 20, is presented with minor editorial revisions in the following paragraph.

The Aviation Review Committee raised the question of the cost benefit to be obtained from a change in control procedure on the North Atlantic to enable all aircraft to execute a step-climb or cruise climb procedure at the option of the operator, i.e., to change to an effectively single layer system no longer using separation in the vertical plane. One important proviso is that horizontal separation standards must first be reduced sufficiently to maintain adequate capacity for the traffic; that is the number of slots in the system must be comparable with the current multi-layer system. One system which is adequate in this regard is Configuration 19 in which lateral and longitudinal separation standards are assumed to be reduced to 15 nmi and 2 min respectively in 1995 by use of cooperative independent surveillance. It was

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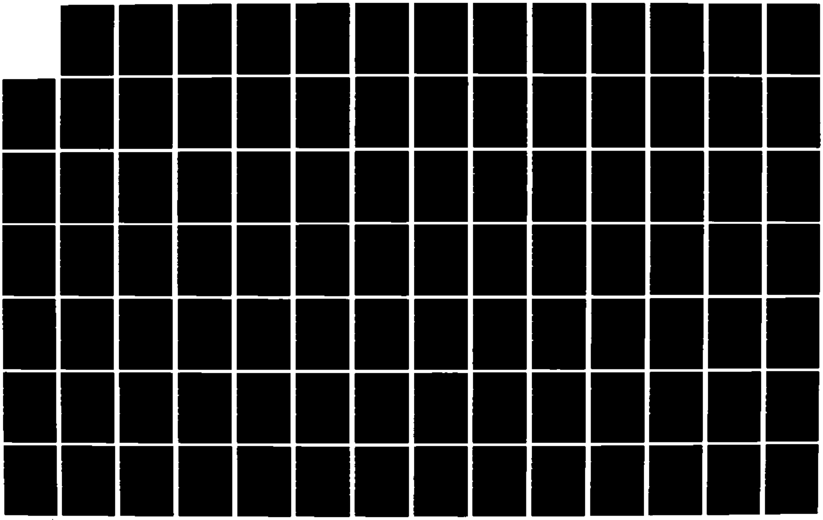

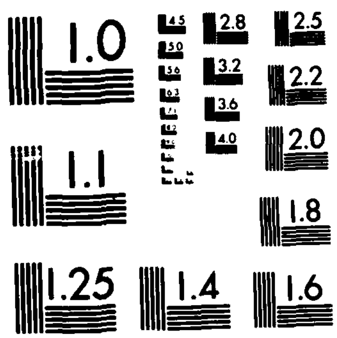

MICROCOPY RESOLUTION TEST CHART
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recommended that a new Configuration 20 should be added in which the separation standards remain as in Configuration 19, but the control procedure is amended so as to bring into existence the single-layer system. Specifically this implies a clearance control procedure whereby no two aircraft are admitted to a single track without adequate longitudinal separation, whatever their respective altitudes (unless their natural altitude separation is large). The Configuration 19, like all other Configurations addressed in this study, imply clearance control procedures similar to those in current use (ref. 2).

The Configuration 20 provider and user cost estimates, except for user flight costs, would be the same as those of Configuration 19 and are shown in Table 8-21. The UK did not provide data describing annual user flight costs corresponding to single layer operations, and, since the FCM was not specified to analyze single layer operations, such cost data is not available and is not shown in Table 8-21. However, the UK did provide an estimate of single layer user flight cost savings for a multi-year period which are presented in Section 9.

8.2.14 Configurations 21. Configuration 19 + 60-30 Composite

An improvement configuration was considered based on the assumption that the 60-30 nmi OTS composite separation minima with MNPS and HF SSB voice communication of Configuration 2 are implemented in 1985, and that the previously identified improvements associated with Configuration 19, including 15 nmi lateral and 2 min longitudinal minima starting in 1995, are implemented separately as part of Configuration 21. The Aviation Review Committee noted however, that uncertainties stand in the way of implementing 60-30 nmi composite as described in Section 8.2.2 (ref. 1). The Configuration 21 cost estimates are shown in Table 8-22.

8.3 References

1. Committee to Review the Application of Satellite and Other Techniques to Civil Aviation; "Report of the 5th Meeting of the Committee, 8-17 December, 1980, Torremolinos/Malaga, Spain", (March 1981).

2. V. W. Attwooll, "The Cost Benefit of a Single Layer North Atlantic System," UK Civil Aviation Authority, Draft Manuscript (March 1981).

TABLE 8-21
COST SUMMARY FOR NAT CONFIGURATION 20:
COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE AND FREE VERTICAL FLIGHT

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	*	*	*	30.800	*	*	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	*	*	*	31.540	*	*	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	*	*	*	32.280	*	*	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	*	*	*	33.020	*	*	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	*	*	*	33.880	*	*	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	*	*	*	34.630	*	*	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	*	*	*	35.500	*	*	1985
1986	1.500	0.000	1.500	11.57	24.80	36.37	0.000	0.000	0.000	*	*	*	37.870	*	*	1986
1987	1.500	0.000	1.500	11.85	25.40	37.25	0.000	0.000	0.000	*	*	*	38.750	*	*	1987
1988	7.533	0.000	7.533	12.13	26.00	38.13	0.000	0.000	0.000	*	*	*	45.663	*	*	1988
1989	7.533	0.000	7.533	12.42	26.60	39.02	0.000	0.000	0.000	*	*	*	46.553	*	*	1989
1990	9.011	0.000	9.011	12.72	27.30	40.02	28.928	1.250	30.178	*	*	*	49.031	*	*	1990
1991	20.678	0.100	20.778	13.03	27.90	40.93	28.928	1.279	30.207	*	*	*	61.708	*	*	1991
1992	10.478	0.200	10.678	13.34	28.60	41.94	28.928	1.309	30.237	*	*	*	52.618	*	*	1992
1993	7.178	0.650	7.828	13.66	29.30	42.96	1.904	1.340	3.244	*	*	*	50.788	*	*	1993
1994	0.000	0.650	0.650	13.99	30.00	43.99	1.904	1.372	3.276	*	*	*	44.640	*	*	1994
1995	0.000	0.650	0.650	4.73	30.70	35.43	1.904	1.404	3.308	*	*	*	36.080	*	*	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.904	1.437	3.341	*	*	*	36.890	*	*	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.904	1.470	3.374	*	*	*	37.810	*	*	1997
1998	11.400	0.650	12.050	5.08	33.00	38.08	1.904	1.503	3.407	*	*	*	50.130	*	*	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.904	1.538	3.442	*	*	*	39.550	*	*	1999
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.904	1.573	3.477	*	*	*	47.270	*	*	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.904	1.610	3.514	*	*	*	41.500	*	*	2001
2002	0.000	0.650	0.650	5.58	36.20	41.78	1.904	1.647	3.551	*	*	*	42.430	*	*	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.904	1.684	3.588	*	*	*	43.470	*	*	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.904	1.723	3.627	*	*	*	44.500	*	*	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.904	1.763	3.667	*	*	*	46.540	*	*	2005

TABLE 8-22
COST SUMMARY FOR NAT CONFIGURATION 21:
COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK
AND VOICE WITH 60-30 COMPOSITE AND MNPS

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.988	1984
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2781.97	1453.16	4235.13	35.500	4235.129	4270.625	1985
1986	1.500	0.000	1.500	11.57	24.80	36.37	0.000	0.000	0.000	2891.40	1502.33	4393.73	37.870	4393.727	4431.594	1986
1987	1.500	0.000	1.500	11.85	25.40	37.25	0.000	0.000	0.000	3005.14	1553.16	4558.30	38.750	4558.297	4597.043	1987
1988	7.533	0.000	7.533	12.13	26.00	38.13	0.000	0.000	0.000	3123.35	1605.72	4729.07	45.663	4729.066	4774.727	1988
1989	7.533	0.000	7.533	12.42	26.60	39.02	0.000	0.000	0.000	3246.22	1660.05	4906.27	46.553	4906.270	4952.820	1989
1990	9.011	0.000	9.011	12.72	27.30	40.02	28.928	1.250	30.178	3373.91	1716.22	5090.13	49.031	5120.305	5169.332	1990
1991	20.678	0.100	20.778	13.03	27.90	40.93	28.928	1.279	30.207	3506.63	1774.29	5280.92	61.708	5311.121	5372.828	1991
1992	10.478	0.200	10.678	13.34	28.60	41.94	28.928	1.309	30.237	3644.57	1834.33	5478.90	52.618	5509.133	5561.750	1992
1993	7.178	0.650	7.828	13.66	29.30	42.96	1.904	1.340	3.244	3787.93	1896.39	5684.32	50.788	5687.559	5738.344	1993
1994	0.000	0.650	0.650	13.99	30.00	43.99	1.904	1.372	3.276	3936.93	1960.56	5897.49	44.640	5900.762	5945.398	1994
1995	0.000	0.650	0.650	4.73	30.70	35.43	1.904	1.404	3.308	4073.61	2025.31	6098.92	36.080	6102.223	6138.301	1995
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.904	1.437	3.341	4208.31	2087.97	6296.28	36.890	6299.617	6336.504	1996
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.904	1.470	3.374	4347.47	2152.56	6500.03	37.810	6503.398	6541.207	1997
1998	11.400	0.650	12.050	5.08	33.00	38.08	1.904	1.503	3.407	4491.22	2219.16	6710.38	50.130	6713.781	6763.910	1998
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.904	1.538	3.442	4639.73	2287.81	6927.54	39.550	6930.980	6970.527	1999
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.904	1.573	3.477	4793.16	2358.59	7151.75	47.270	7155.227	7202.496	2000
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.904	1.610	3.514	4951.65	2431.56	7383.21	41.500	7386.719	7428.215	2001
2002	0.000	0.650	0.650	5.58	36.20	41.78	1.904	1.647	3.551	5115.39	2506.78	7622.17	42.430	7625.719	7668.148	2002
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.904	1.684	3.588	5284.54	2584.33	7868.87	43.470	7872.453	7915.922	2003
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.904	1.723	3.627	5459.28	2664.28	8123.56	44.500	8127.184	8171.680	2004
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.904	1.763	3.667	5639.80	2746.71	8386.51	46.540	8390.172	8436.711	2005

9.0 NAT CONFIGURATIONS COST COMPARISONS

9.1 Cost Data for Comparisons

The user and provider capital and O&M estimated total costs for the 1979 through 2005 time period for each configuration are summarized in Table 9-1. These total cost estimates were obtained by summing the corresponding annual cost estimates presented in Section 8. The data in Table 9-1 are stated in 1979 US$ (i.e., 1979 prices are applied in each year) and do not include inflationary effects. To provide a meaningful cost comparison in this section, the cost data will be inflated in each year of outlay based on the assumptions that fuel costs will increase at a 10% annually compounded rate and all other costs (capital and non-fuel O&M expenditures) will increase at an 8% annually compounded rate beginning in mid-1979.

Another factor that must be considered in comparing configuration costs is the timing of an investment or other expenditure. A decision to invest in an alternative in a given year foregoes the opportunity to invest that same money in a competing alternative and at a later time. The money could have been invested in an interest-bearing account, for example, or, equivalently, in a revenue producing asset during the time period under study. The question arises as to how to determine the relative value of a dollar spent today (or any given year) versus a dollar spent in a subsequent year and taking into account the revenue producing value of the investments over time. Traditionally, investment projects are evaluated by expressing all present (i.e., base year) and future expenses and revenues as if they all occurred today. This process, termed discounting, results in estimating the present value of expenses and revenues. For example, the present value of $100 two years from today, assuming a 10% discount rate (or rate of return or interest rate), is $82.64.

The present value procedure will be used to compare the total cost of each configuration accumulated over the 1979 through 2005 study period, and involves discounting and summing the expenditures estimated in each and every year to their mid-1979 base year present value. A single present value total cost will be obtained for each configuration. Since the discount rate should represent the rate of return expected by the investor, a 10% discount rate is assumed for provider authority costs and a 12% discount rate is assumed for user costs. The discount and inflation rates are summarized in Table 9-2.

TABLE 9-1

COST SUMMARY TOTALS OVER ALL YEARS FOR ALL NAT CONFIGURATIONS

(1979 US $ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			
CONFIG URATION	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	CONFIG URATION
1	0.000	0.000	0.000	366.36	785.00	1151.36	0.000	0.000	0.000	101130.900	50894.320	152025.200	1151.358	152025.200	153176.400	1
2	0.000	0.000	0.000	366.36	785.00	1151.36	0.000	0.000	0.000	101051.500	50853.640	151905.000	1151.358	151905.000	153056.500	2
3	0.000	0.000	0.000	366.36	785.00	1151.36	0.000	0.000	0.000	101051.500	50853.640	151905.000	1151.358	151905.000	153056.500	3
4	6.000	0.000	6.000	366.36	785.00	1151.36	0.000	0.000	0.000	100519.500	50884.580	151404.000	1157.358	151404.000	152561.200	4
5	6.000	0.000	6.000	366.36	785.00	1151.36	16.293	1.665	17.958	100574.300	50885.830	151460.000	1157.358	151477.900	152635.300	5
6	6.000	0.000	6.000	366.36	785.00	1151.36	0.000	0.000	0.000	100303.600	50880.770	151184.300	1157.358	151184.300	152341.700	6
7	6.000	0.000	6.000	366.36	785.00	1151.36	16.293	1.665	17.958	100379.700	50882.970	151262.600	1157.358	151280.600	152437.800	7
8	1.000	0.000	1.000	366.36	785.00	1151.36	100.815	29.731	130.546	100902.600	50851.480	151753.900	1152.358	151884.500	153036.600	8
9	1.000	0.000	1.000	366.36	785.00	1151.36	50.409	29.731	80.140	100902.600	50851.400	151753.900	1152.358	151834.000	152986.300	9
10	47.480	30.900	78.380	224.46	785.00	1009.46	85.707	29.731	115.438	100902.600	50851.400	151753.900	1087.838	151869.300	152957.100	10
11	48.480	30.900	79.380	224.46	785.00	1009.46	136.116	59.462	195.578	100902.600	50851.400	151753.900	1088.838	151949.400	153038.100	11
12	39.229	16.650	55.879	220.18	785.00	1005.18	42.868	29.731	72.599	101130.900	50894.320	152025.200	1061.056	152097.600	153158.600	12
13	39.229	16.650	55.879	220.18	785.00	1005.18	85.746	29.731	115.477	100932.900	50857.670	151790.500	1061.056	151906.000	152966.900	13
14	40.229	16.650	56.879	220.18	785.00	1005.18	149.026	56.047	205.073	100932.900	50857.670	151790.500	1062.056	151995.500	153057.500	14
15	82.711	12.000	94.711	202.47	785.00	987.47	101.298	29.731	131.029	100902.600	50851.400	151753.900	1082.178	151884.800	152967.000	15
16	83.711	12.000	95.711	202.47	785.00	987.47	151.707	59.462	211.169	100902.600	50851.400	151753.900	1083.178	151965.000	153048.100	16
17	63.882	12.000	75.882	202.47	785.00	987.47	69.408	29.731	99.139	100902.600	50851.400	151753.900	1063.349	151853.000	152916.300	17
18	64.882	12.000	76.882	202.47	785.00	987.47	119.817	59.462	179.279	100902.600	50851.400	151753.900	1064.349	151933.100	152997.500	18
19	84.511	8.750	93.261	247.18	785.00	1032.18	111.536	23.902	135.438	100817.100	50850.560	151667.600	1125.438	151802.900	152928.300	19
20	84.511	8.750	93.261	247.18	785.00	1032.18	111.536	23.902	135.438	*	*	*	1125.438	*	*	20
21	84.511	8.750	93.261	247.18	785.00	1032.18	111.536	23.902	135.438	100794.300	50838.500	151632.600	1125.438	151768.000	152893.500	21

* Data not available

ALTERNATIVE NUMBER	ALTERNATIVE NAME
1	BASELINE
2	60-30 COMPOSITE WITH MNPS
3	60-30 COMPOSITE WITH MNPS(I)
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
5	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY
6	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
7	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC WITH IMPROVED ALTIMETRY
8	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
9	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
10	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
11	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
12	SIMPLE NETWORK HF DATA LINK AND VOICE WITHOUT SEPARATION MINIMA REDUCTION
13	SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION
14	SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
15	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE
16	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
17	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE, DATA LINK ONLY
18	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK ONLY AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
19	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE
20	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE AND FREE VERTICAL FLIGHT
21	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE WITH 60-30 COMPOSITE AND MNPS

Table 9-2

ASSUMED INFLATION AND DISCOUNT RATES

Cost Category	Inflation Rate
Fuel	10%
Other	8%

Investor	Discount Rate
User	12%
Provider	10%

Source: The indicated rates are estimated by SRI International from long-term forecasts developed by Chase Econometrics.

The present value calculation process used in this analysis includes an annualization (i.e., amortization or capitalization) of capital costs over the life of the capital equipment. The annualization life for each user and provider capital cost is assumed to be 20 years, except for satellite space segment capital costs, which are annualized over a 7 year period. The annualization process translates each capital cost into an equivalent stream of annual costs over the life of the equipment, which are discounted to their present value. Capitalized annual costs that are allocated into the years after 2005 are not included in the present value total costs because their corresponding revenues (e.g., reduced user costs) are not represented in the years outside the 1979 through 2005 study period. As a result, part, but not all, of the discounted value of certain capital outlays made during the latter years in the study period are included in the present value totals. Apart from the capital costs, all O&M costs originally were estimated on an annual basis and their full discounted values are included in the present value totals.

9.2 Present Value Cost Comparison

The 1979 present values of the outlays during the 1979 through 2005 time period for each configuration are shown in Table 9-3. Table 9-4 is a simplified version of Table 9-3, and was constructed by combining the Table 9-3 data into user and provider capital, O&M and total cost categories. These costs include inflation effects. The user capital costs represent aircraft equipment improvements, and user operating costs include the improvement O&M costs plus the fuel, crew, and maintenance flight costs. Provider capital costs represent the improvement implementations, and provider operating costs include the improvement O&M outlays plus the COM and ATS facility O&M costs.

While the discounted costs shown in Tables 9-3 or 9-4 enable comparisons between the total study period expenditures of implementing each configuration, a convenient analysis of the relative efficiencies of the configurations may be made by examining the cost differences between configurations. For this purpose, the 1979 present values of the net savings achievable by each configuration relative to the baseline configuration are shown in Table 9-5. These savings data simply are the baseline configuration cost entries in Table 9-3 minus the corresponding cost entries of each alternative configuration. Table 9-6 is a simplified version of Table 9-5, and shows the discounted net savings data arranged into user and provider capital, O&M and total cost categories.

Recall that user flight costs for Configuration 20, which includes clearance control procedures permitting exploitation of free flight in the vertical plane, were not based on FCM evaluations. Rather the present value of the user flight cost savings during 1979 through 2005 were provided by the UK with the following explanation: The results in terms of cost saving for Configuration 20 amount to a decrease in operating cost of $108 million arising from the change to the single layer

TABLE 9-3

PRESENT VALUE COST SUMMARY TOTALS OVER ALL YEARS FOR ALL NAT CONFIGURATIONS

(1979 DISCOUNTED US $ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			
CONFIG URATION	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	CONFIG URATION
1	0.	0.	0.	284.	608.	892.	0.	0.	0.	77652.	30769.	108420.	892.	108420.	109313.	1
2	0.	0.	0.	284.	608.	892.	0.	0.	0.	77595.	30748.	108342.	892.	108342.	109235.	2
3	0.	0.	0.	284.	608.	892.	0.	0.	0.	77595.	30748.	108342.	892.	108342.	109235.	3
4	6.	0.	6.	284.	608.	892.	0.	0.	0.	77204.	30763.	107967.	898.	107967.	108865.	4
5	6.	0.	6.	284.	608.	892.	11.	1.	12.	77252.	30764.	108016.	898.	108028.	108926.	5
6	6.	0.	6.	284.	608.	892.	0.	0.	0.	77045.	30761.	107806.	898.	107806.	108704.	6
7	6.	0.	6.	284.	608.	892.	11.	1.	12.	77112.	30762.	107874.	899.	107886.	108785.	7
8	1.	0.	1.	284.	608.	892.	64.	17.	80.	77490.	30747.	108237.	893.	108317.	109211.	8
9	1.	0.	1.	284.	608.	892.	32.	17.	48.	77490.	30747.	108237.	893.	108286.	109179.	9
10	40.	23.	63.	184.	608.	792.	54.	17.	70.	77490.	30747.	108237.	855.	108307.	109162.	10
11	41.	23.	64.	184.	608.	792.	86.	33.	119.	77490.	30747.	108237.	856.	108356.	109212.	11
12	33.	12.	45.	180.	608.	788.	24.	17.	41.	77652.	30769.	108420.	833.	108461.	109294.	12
13	33.	12.	45.	180.	608.	788.	43.	17.	60.	77515.	30751.	108266.	833.	108326.	109159.	13
14	34.	12.	46.	180.	608.	788.	78.	30.	108.	77515.	30751.	108266.	834.	108374.	109209.	14
15	65.	9.	74.	168.	608.	776.	64.	17.	80.	77490.	30747.	108237.	850.	108317.	109168.	15
16	66.	9.	75.	168.	608.	776.	96.	33.	129.	77490.	30747.	108237.	851.	108366.	109217.	16
17	51.	9.	60.	168.	608.	776.	44.	17.	60.	77490.	30747.	108237.	836.	108297.	109134.	17
18	52.	9.	61.	168.	608.	776.	76.	33.	109.	77490.	30747.	108237.	837.	108346.	109183.	18
19	58.	6.	64.	203.	608.	812.	51.	12.	63.	77438.	30748.	108187.	876.	108250.	109126.	19
20	58.	6.	64.	203.	608.	812.	51.	12.	63.	*	*	108120.	876.	108184.	109060.	20
21	58.	6.	64.	203.	608.	812.	51.	12.	63.	77420.	30740.	108160.	876.	108223.	109099.	21

* Data not available

ALTER-NATIVE NUMBER	ALTER-NATIVE NAME
1	BASELINE
2	60-30 COMPOSITE WITH MNPS
3	60-30 COMPOSITE WITH MNPS(I)
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
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14	SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
15	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE
16	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
17	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE, DATA LINK ONLY
18	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK ONLY AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
19	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE
20	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE AND FREE VERTICAL FLIGHT
21	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE WITH 60-30 COMPOSITE AND MNPS

TABLE 9-4
PRESENT VALUE 1979-2005 NAT CONFIGURATIONS COSTS
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	108420.	108420.	0.	892.	892.	0.	109313.	109313.	BASELINE
2	0.	108342.	108342.	0.	892.	892.	0.	109234.	109234.	60-30 COMPOSITE, MNPS
3	0.	108342.	108342.	0.	892.	892.	0.	109234.	109234.	60-30 COMPOSITE, MNPS(I)
4	0.	107967.	107967.	6.	892.	898.	6.	108859.	108865.	1000 FT OCEANIC
5	11.	108017.	108028.	6.	892.	898.	17.	108909.	108926.	1000 FT OCEANIC + ALTIMETRY
6	0.	107806.	107806.	6.	892.	898.	6.	108698.	108704.	1000 FT EVERYWHERE
7	11.	107875.	107886.	6.	892.	898.	17.	108768.	108784.	1000 FT EVERYWHERE + ALTIMETRY
8	64.	108254.	108317.	1.	892.	893.	65.	109146.	109211.	SEP AS DEV, 100% AVIONICS COST
9	32.	108254.	108286.	1.	892.	893.	33.	109146.	109179.	SEP AS DEV, 50% AVIONICS COST
10	54.	108254.	108307.	40.	815.	855.	94.	109068.	109162.	ADS, NETWORK HF
11	86.	108270.	108356.	41.	815.	856.	127.	109085.	109212.	ADS, NETWORK HF, SEP AS DEV-50%
12	24.	108437.	108461.	33.	801.	833.	57.	109237.	109294.	SIMPLE HF,NO SEP MIN REDUCTION
13	43.	108282.	108326.	33.	801.	833.	76.	109083.	109159.	SIMPLE HF,MIN RED
14	78.	108296.	108374.	34.	801.	834.	112.	109097.	109208.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	64.	108254.	108317.	65.	785.	850.	129.	109039.	109168.	ADS, SAT
16	96.	108270.	108366.	66.	785.	851.	162.	109055.	109217.	ADS, SAT, SEP AS DEV-50%
17	44.	108254.	108297.	51.	785.	836.	95.	109039.	109134.	ADS, SAT DL ONLY
18	76.	108270.	108346.	52.	785.	837.	128.	109055.	109183.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	51.	108199.	108250.	58.	818.	876.	109.	109017.	109126.	CIS, MULTI SAT
20	51.	108132.	108183.	58.	818.	876.	109.	108950.	109060.	CIS, MULTI SAT, FREE VERT FLIGHT
21	51.	108172.	108223.	58.	818.	876.	109.	108990.	109099.	CIS, MULTI SAT, 60-30 C, MNPS

TABLE 9-5

PRESENT VALUE NET SAVINGS TOTALS OVER ALL YEARS FOR EACH NAT CONFIGURATION

(1979 DISCOUNTED US $ MILLIONS)

CONFIG URATION	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			CONFIG URATION
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	57.	21.	78.	0.	78.	78.	2
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	57.	21.	78.	0.	78.	78.	3
4	-6.	0.	-6.	0.	0.	0.	0.	0.	0.	448.	6.	453.	-6.	453.	448.	4
5	-6.	0.	-6.	0.	0.	0.	-11.	-1.	-12.	399.	5.	404.	-6.	392.	387.	5
6	-6.	0.	-6.	0.	0.	0.	0.	0.	0.	606.	8.	615.	-6.	615.	609.	6
7	-6.	0.	-6.	0.	0.	0.	-11.	-1.	-12.	539.	6.	546.	-6.	534.	528.	7
8	-1.	0.	-1.	0.	0.	0.	-64.	-17.	-80.	161.	22.	183.	-1.	103.	102.	8
9	-1.	0.	-1.	0.	0.	0.	-32.	-17.	-48.	161.	22.	183.	-1.	135.	134.	9
10	-40.	-23.	-63.	100.	0.	100.	-54.	-17.	-70.	161.	22.	183.	38.	113.	150.	10
11	-41.	-23.	-64.	100.	0.	100.	-86.	-33.	-119.	161.	22.	183.	37.	65.	101.	11
12	-33.	-12.	-45.	104.	0.	104.	-24.	-17.	-41.	0.	0.	0.	59.	-41.	18.	12
13	-33.	-12.	-45.	104.	0.	104.	-43.	-17.	-60.	137.	18.	155.	59.	95.	154.	13
14	-34.	-12.	-46.	104.	0.	104.	-78.	-30.	-108.	137.	18.	155.	58.	46.	104.	14
15	-65.	-9.	-74.	116.	0.	116.	-64.	-17.	-80.	161.	22.	183.	42.	103.	145.	15
16	-66.	-9.	-75.	116.	0.	116.	-96.	-33.	-129.	161.	22.	183.	41.	55.	96.	16
17	-51.	-9.	-60.	116.	0.	116.	-44.	-17.	-60.	161.	22.	183.	56.	123.	179.	17
18	-52.	-9.	-61.	116.	0.	116.	-76.	-33.	-109.	161.	22.	183.	55.	74.	130.	18
19	-58.	-6.	-64.	81.	0.	81.	-51.	-12.	-63.	213.	20.	234.	16.	170.	187.	19
20	-58.	-6.	-64.	81.	0.	81.	-51.	-12.	-63.	*	*	300.	16.	237.	253.	20
21	-58.	-6.	-64.	81.	0.	81.	-51.	-12.	-63.	232.	28.	261.	16.	197.	214.	21

* Data not available

CONFIGURATION NUMBER	CONFIGURATION NAME
1	BASELINE
2	60-30 COMPOSITE WITH MNPS
3	60-30 COMPOSITE WITH MNPS(I)
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
5	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY
6	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
7	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC WITH IMPROVED ALTIMETRY
8	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
9	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
10	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
11	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
12	SIMPLE NETWORK HF DATA LINK AND VOICE WITHOUT SEPARATION MINIMA REDUCTION
13	SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION
14	SIMPLE NETWORK HF DATA LINK AND VOICE WITH SEPARATION MINIMA REDUCTION AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
15	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE
16	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
17	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE, DATA LINK ONLY
18	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK ONLY AND SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
19	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE
20	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE AND FREE VERTICAL FLIGHT
21	COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE DATA LINK AND VOICE WITH 60-30 COMPOSITE AND MNPS

system and a decrease in operating cost of $192 million due to the reduction in separation standards (the latter figure is somewhat lower than the corresponding decrease for Configuration 19; this is because the more restrictive entry control procedure leads to a greater incidence of lateral deviations in the system). However, the sum total of $300 million shows a substantial gain in favour of the single layer system variant (ref. 1). The $300 million is used for the user flight O&M total cost saving shown in Table 9-5 for Configuration 20.

9.2.1 1000 ft Vertical Separation Above FL 290

In Table 9-6, the right-hand total cost column includes the net savings associated with the vertical separation minimum reduction to 1000 ft in oceanic (Configuration 4) and in oceanic and domestic airspace (Configuration 6) in 1985 without altimetry system and height keeping improvements. These configurations obtain net savings of $448 and $609 million respectively. These savings are somewhat reduced if altimetry improvements (and their associated user capital and O&M costs) are required and implementation is delayed to 1988 (i.e., Configurations 5 and 7). The savings are still very large at $387 and $528 million respectively.

The capital and O&M cost estimates for altimetry improvements (see Section 5) are based on limited information concerning the specific technological approaches likely to be used. These improvement cost estimates are subject to revision and an examination of the resulting impact of such revisions on their present value net savings is appropriate. For example, if the capital costs for the aircraft equipment associated with Configurations 5 and 7 were underestimated by a factor of two or if the inflation effects were similarly underestimated, the net increase in user capital costs ($11 million) shown in Table 9-6 should be doubled. This calculation will reduce net savings slightly, but the savings will remain very large, indicating that the 1000 ft vertical separation minimum is meaningfully attractive in economic terms. The same conclusion would be developed if the net savings sensitivities to variations in user operating costs were similarly examined (i.e., doubling user avionics O&M costs would not significantly alter the net savings results).

9.2.2 Separation Assurance Device

The implementation of the separation assurance device with 100% avionics capital cost allocation to NAT operations (Configuration 8), MNPS (Improved), and 30 nmi/5 min/2000 ft separation minima in 1990 also shows a significant net savings of $102 million. In this case, the user capital cost net increase ($64 million) and provider capital cost net increase ($1 million) is more than offset by the large net savings in user operating costs ($167 million). Even if the user capital costs were underestimated by 50% (i.e., capital cost net increases are actually half again those indicated), significant net savings still

TABLE 9-6

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS CAPITAL COST	USERS OPERATING COST	USERS TOTAL COST	PROVIDERS CAPITAL COST	PROVIDERS OPERATING COST	PROVIDERS TOTAL COST	USERS + PROVIDERS CAPITAL COST	USERS + PROVIDERS OPERATING COST	USERS + PROVIDERS TOTAL COST	CONFIG-URATION NAME
1	0.	0.	-0.	0.	0.	0.	0.	0.	0.	BASELINE
2	0.	78.	78.	0.	0.	0.	0.	78.	78.	60-30 COMPOSITE, MNPS
3	0.	78.	78.	0.	0.	0.	0.	78.	78.	60-30 COMPOSITE, MNPS(I)
4	0.	453.	453.	-6.	0.	-6.	-6.	453.	448.	1000 FT OCEANIC
5	-11.	403.	392.	-6.	0.	-6.	-17.	403.	387.	1000 FT OCEANIC + ALTIMETRY
6	0.	615.	615.	-6.	0.	-6.	-6.	615.	609.	1000 FT EVERYWHERE
7	-11.	545.	534.	-6.	0.	-6.	-17.	545.	528.	1000 FT EVERYWHERE + ALTIMETRY
8	-64.	167.	103.	-1.	0.	-1.	-65.	167.	102.	SEP AS DEV, 100% AVIONICS COST
9	-32.	167.	135.	-1.	0.	-1.	-33.	167.	134.	SEP AS DEV, 50% AVIONICS COST
10	-54.	167.	113.	-40.	78.	38.	-94.	244.	150.	ADS, NETWORK HF
11	-86.	150.	65.	-41.	78.	37.	-127.	228.	101.	ADS, NETWORK HF, SEP AS DEV-50%
12	-24.	-16.	-41.	-33.	92.	59.	-57.	75.	18.	SIMPLE HF,NO SEP MIN REDUCTION
13	-43.	138.	95.	-33.	92.	59.	-76.	230.	154.	SIMPLE HF,MIN RED
14	-78.	124.	46.	-34.	92.	58.	-112.	216.	104.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-64.	167.	103.	-65.	107.	42.	-129.	274.	145.	ADS, SAT
16	-96.	150.	55.	-66.	107.	41.	-162.	257.	96.	ADS, SAT, SEP AS DEV-50%
17	-44.	167.	123.	-51.	107.	56.	-95.	274.	179.	ADS, SAT DL ONLY
18	-76.	150.	74.	-52.	107.	55.	-128.	257.	130.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-51.	222.	170.	-58.	75.	16.	-109.	296.	187.	CIS, MULTI SAT
20	-51.	288.	237.	-58.	75.	16.	-109.	363.	253.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-51.	248.	197.	-58.	75.	16.	-109.	323.	214.	CIS, MULTI SAT, 60-30 C, MNPS

would be obtained, which indicates that this configuration is economically attractive. The separation assurance device with 50% avionics capital cost allocation to NAT operation (Configuration 9) would further increase the economic gains because of lower capital costs relative to the 100% allocation as indicated by the net savings of $134 million shown in Table 9-6.

9.2.3 60-30 nmi Composite

The implementation of the 60-30 nmi/10 min/2000 ft OTS composite minima (Configuration 2) in 1985 without technological improvements shows a net savings of $78 million. This operation assumes that current navigation systems accuracies will support the reduced minima. However, the conditions outlined previously in Section 4.3 regarding the 60-30 nmi composite structure must be resolved prior to its implementation.

9.2.4 HF and Satellite Improvements

The configurations involving automatic dependent surveillance with 30 nmi/5 min/2000 ft separations, cooperative independent surveillance with 15 nmi/2 min/2000 ft, and related technological combinations and derivatives (i.e., Configurations 10 through 21) all show a net savings in total costs in Table 9-6. The capital and O&M cost estimates made for these potential improvements were based on a number of data sources and a variety of assumptions addressing numerous technical components and changes in these assumptions could revise the estimated costs. Such revisions could also affect net savings. Therefore, an examination of the sensitivity of the net cost savings to parametric adjustments to some key component costs is appropriate and is addressed in the following paragraphs.

9.3 Sensitivity Analysis of Selected Improvement Costs

The magnitude of several important system design parameters and associated costs may change significantly based on additional information in the future and on further detailed analysis. These parameters include aircraft fleet size, satellite spacecraft and avionics equipment design and costs, and ATS facility O&M costs.

9.3.1 Aircraft Fleet Size

Since the aircraft communications equipment improvement capital cost (which is a linear function of fleet size) is a large part of any system considered, 20% and 40% reductions in user capital costs are examined for sensitivity analysis purposes. The net cost results for these two cost reduction respectively are shown in Table 9-7 and 9-8. Comparisons of these tables with Table 9-6 shows that the 20% reduction in fleet size furthers net savings by 4% to 26%, and the 40% reduction in fleet size furthers net saings by 8% to over 50%.

TABLE 9-7

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
20% REDUCTION IN USER AVIONICS CAPITAL COST

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10	-43.	167.	124.	-40.	78.	38.	-83.	244.	161.	ADS, NETWORK HF
11	-68.	150.	82.	-41.	78.	37.	-109.	228.	118.	ADS, NETWORK HF, SEP AS DEV-50%
12	-19.	-16.	-36.	-33.	92.	59.	-52.	75.	23.	SIMPLE HF,NO SEP MIN REDUCTION
13	-35.	138.	104.	-33.	92.	59.	-68.	230.	162.	SIMPLE HF,MIN RED
14	-62.	124.	62.	-34.	92.	58.	-96.	216.	120.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-51.	167.	116.	-65.	107.	42.	-116.	274.	158.	ADS, SAT
16	-76.	150.	74.	-66.	107.	41.	-143.	257.	115.	ADS, SAT, SEP AS DEV-50%
17	-35.	167.	132.	-51.	107.	56.	-86.	274.	188.	ADS, SAT DL ONLY
18	-60.	150.	90.	-52.	107.	55.	-112.	257.	145.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-41.	222.	181.	-58.	75.	16.	-99.	296.	197.	CIS, MULTI SAT
20	-41.	288.	247.	-58.	75.	16.	-99.	363.	263.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-41.	248.	207.	-58.	75.	16.	-99.	323.	224.	CIS, MULTI SAT, 60-30 C, MNPS

TABLE 9-8

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
40% REDUCTION IN USER AVIONICS CAPITAL COST

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10	-32.	167.	134.	-40.	78.	38.	-72.	244.	172.	ADS, NETWORK HF
11	-51.	150.	99.	-41.	78.	37.	-92.	228.	135.	ADS, NETWORK HF, SEP AS DEV-50%
12	-15.	-16.	-31.	-33.	92.	59.	-47.	75.	28.	SIMPLE HF,NO SEP MIN REDUCTION
13	-26.	138.	112.	-33.	92.	59.	-59.	230.	171.	SIMPLE HF,MIN RED
14	-47.	124.	77.	-34.	92.	58.	-81.	216.	135.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-38.	167.	128.	-65.	107.	42.	-103.	274.	170.	ADS, SAT
16	-57.	150.	93.	-66.	107.	41.	-123.	257.	134.	ADS, SAT, SEP AS DEV-50%
17	-26.	167.	140.	-51.	107.	56.	-77.	274.	197.	ADS, SAT DL ONLY
18	-45.	150.	105.	-52.	107.	55.	-97.	257.	160.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-31.	222.	191.	-58.	75.	16.	-89.	296.	207.	CIS, MULTI SAT
20	-31.	288.	257.	-58.	75.	16.	-89.	363.	274.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-31.	248.	218.	-58.	75.	16.	-89.	323.	234.	CIS, MULTI SAT, 60-30 C, MNPS

9.3.2 User Avionics Capital Costs

The capital equipment costs of the avionics system may vary. For example, it may be found that the proposed HF antenna couplers or modems may be more expensive than estimated. An extreme underestimate might increase retrofit aircraft costs by $40 to $50 thousand per aircraft although increases of $10 to 20 thousand per aircraft probably bound the cost uncertainties. Similarly, a requirement to place L-band amplifiers in an avionics rack far from the antenna could increase satellite data and voice avionics by several thousand dollars or more. These avionics cost uncertainties have motivated recalculation of the Configuration 10 through 21 costs with both 20% and 40% increases in capital costs of avionics as shown in Tables 9-9 and 9-10 respectively. Comparisons of these tables with Table 9-6 shows that the 20% cost increase reduces estimated net savings by 4% to 26% and the 40% cost increase reduces estimated net savings by 8% to almost 50%. In each case, the net savings remain positive.

9.3.3 Provider Capital Costs

Ground station costs associated with the network and simple network HF data link and voice improvements involve many variables such as land costs, software costs, etc., all of which can only be judgmentally estimated until specific engineering data are developed for existing HF SSB facilities. Hence, the analysis of the sensitivity of network HF data link and voice costs (exclusive of feasibility study and engineering design costs) to a 50% increase in the cost of implementing a ground network for configurations 10 through 14 is presented in Table 9-11. Comparisons of Table 9-11 with Table 9-6 shows that the 50% increase in the HF capital costs causes a 2% to 11% decrease in net savings for Configuration 10 through 14.

The satellite segment cost estimates were based on an assumed idealized sharing of satellite and launch costs with other users of a space vehicle. The satellite-to-aircraft communications portion of a satellite data plus voice package is estimated to require approximately 275 lbs of satellite dry weight out of a total of about 1100 lbs of total dry weight of the typical satellite being considered. This is 25% of the cost of the satellite, including launch. A space segment package for the automatic dependent surveillance data link and voice or data-only systems could cost more than the idealized 25% allocation. Furthermore, a multiple satellite cooperative independent surveillance system would probably require satellites dedicated to aeronautical services to ensure the necessary orbital location and service level in a timely manner; in this case, the full provider cost allocation should be considered. To investigate such nonoptimum cost sharing arrangements, the FAA has analyzed the cost effects of two situations in which: (1) the space segment provider capital costs for Configurations 15 through 18 are assumed to be 50% of the dedicated satellite operation; and (2) the space segment provider capital costs for Configuration 19, 20 and 21

TABLE 9-9

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE

(1979 DISCOUNTED US $ MILLIONS)

20% INCREASE IN USER AVIONICS CAPITAL COST

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10	-64.	167.	102.	-40.	78.	38.	-105.	244.	140.	ADS, NETWORK HF
11	-103.	150.	47.	-41.	78.	37.	-144.	228.	84.	ADS, NETWORK HF, SEP AS DEV-50%
12	-29.	-16.	-46.	-33.	92.	59.	-62.	75.	14.	SIMPLE HF,NO SEP MIN REDUCTION
13	-52.	138.	86.	-33.	92.	59.	-85.	230.	145.	SIMPLE HF,MIN RED
14	-94.	124.	31.	-34.	92.	58.	-127.	216.	89.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-76.	167.	90.	-65.	107.	42.	-142.	274.	132.	ADS, SAT
16	-115.	150.	36.	-66.	107.	41.	-181.	257.	77.	ADS, SAT, SEP AS DEV-50%
17	-52.	167.	114.	-51.	107.	56.	-103.	274.	170.	ADS, SAT DL ONLY
18	-91.	150.	59.	-52.	107.	55.	-143.	257.	115.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-61.	222.	160.	-58.	75.	16.	-120.	296.	177.	CIS, MULTI SAT
20	-61.	288.	227.	-58.	75.	16.	-120.	363.	243.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-61.	248.	187.	-58.	75.	16.	-120.	323.	203.	CIS, MULTI SAT, 60-30 C, MNPS

TABLE 9-10

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
40% INCREASE IN USER AVIONICS CAPITAL COST

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10	-75.	167.	91.	-40.	78.	38.	-115.	244.	129.	ADS, NETWORK HF
11	-120.	150.	30.	-41.	78.	37.	-161.	228.	67.	ADS, NETWORK HF, SEP AS DEV-50%
12	-34.	-16.	-50.	-33.	92.	59.	-67.	75.	9.	SIMPLE HF,NO SEP MIN REDUCTION
13	-61.	138.	77.	-33.	92.	59.	-94.	230.	136.	SIMPLE HF,MIN RED
14	-109.	124.	15.	-34.	92.	58.	-143.	216.	73.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-89.	167.	77.	-65.	107.	42.	-154.	274.	120.	ADS, SAT
16	-134.	150.	16.	-66.	107.	41.	-200.	257.	57.	ADS, SAT, SEP AS DEV-50%
17	-61.	167.	105.	-51.	107.	56.	-112.	274.	162.	ADS, SAT DL ONLY
18	-106.	150.	44.	-52.	107.	55.	-158.	257.	100.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-72.	222.	150.	-58.	75.	16.	-130.	296.	166.	CIS, MULTI SAT
20	-72.	288.	216.	-58.	75.	16.	-130.	363.	233.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-72.	248.	177.	-58.	75.	16.	-130.	323.	193.	CIS, MULTI SAT, 60-30 C, MNPS

TABLE 9-11

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
SELECTED PROVIDER CAPITAL COST INCREASES

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10*	-54.	167.	113.	-46.	78.	32.	-99.	244.	145.	ADS, NETWORK HF
11*	-86.	150.	65.	-47.	78.	31.	-132.	228.	96.	ADS, NETWORK HF, SEP AS DEV-50%
12*	-24.	-16.	-41.	-36.	92.	56.	-60.	75.	16.	SIMPLE HF,NO SEP MIN REDUCTION
13*	-43.	138.	95.	-36.	92.	56.	-79.	230.	151.	SIMPLE HF,MIN RED
14*	-78.	124.	46.	-36.	92.	55.	-115.	216.	102.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15†	-64.	167.	103.	-112	107.	-59.	-176.	274.	98	ADS, SAT
15†	-96.	150.	55.	-113	107.	-60.	-209.	257.	49	ADS, SAT, SEP AS DEV-50%
17†	-44.	167.	123.	-112	107.	-2.	-156.	274.	118	ADS, SAT DL ONLY
18†	-76.	150.	74.	-113	107.	-3.	-189.	257.	69	ADS, SAT DL ONLY, SEP AS DEV-50%
19§	-51.	222.	170.	-180	75.	-82.	-231.	296.	65	CIS, MULTI SAT
20§	-51.	288.	237.	-180	75.	-82.	-231.	363.	131	CIS, MULTI SAT, FREE VERT FLIGHT
21§	-51.	248.	197.	-180	75.	-82.	-231.	323.	92	CIS, MULTI SAT, 60-30 C, MNPS

*50% Increase in network and simple network HF ground station provider capital cost, excluding feasibility study and engineering design costs.

†50% of dedicated aeronautical space segment provider capital cost.

§100% of dedicated aeronautical space segment provider capital cost.

are assumed to be 100 percent of the dedicated satellite operation. The cost analysis is described in Appendix H and the results are summarized in Table 9-11. Comparison of Table 9-11 with Table 9-6 shows that the 50% cost sharing arrangement causes a 32% to 49% decrease in net savings for Configurations 15 through 19, and the 100% dedicated satellite cost arrangement causes a 57% to 65% decrease in net savings for Configurations 19, 20 and 21.

9.3.4 VHF Satellite Frequencies

The use of VHF, rather than the L-band frequencies, in the satellite-based operations (e.g., Configurations 15 through 21) might involve less expensive avionics equipment costs despite the uncertainties in aircraft antenna costs, and might decrease avionics capital costs by 20% to 40%; the resulting net savings would be the same as those previously shown in Tables 9-7 and 9-8. But, those net savings gains may be counterbalanced by cost increases due to the VHF satellite segment, for which costs were not explicitly estimated because of a lack of data describing component design. The VHF satellite antennas, due to their large size, would make the identification of partners with which to share spacecraft costs difficult. In addition, technical uncertainties related to the performance of VHF remain to be answered, and the VHF frequency allocation is not compatible with supporting the growth requirements of a new system (see Sections 5.3.1 and 3.3).

9.3.5 ATS Facility O&M Costs

The estimated ATS facilities O&M costs for automatic dependent and independent cooperative surveillance operations assumed that these costs would be the same as the baseline configuration O&M costs. Since there is no precedence for an advanced ATC operation of the type envisaged for improved oceanic communication and no design specifications, the preliminary ATS facility O&M cost estimates were based on rough assumptions regarding controller operations (see Section 7). These estimates assumed that staffing, sectorization and equippage growth would be comparable to those of the baseline configuration. While it is not anticipated that the ATS and O&M cost estimates will increase beyond those estimated, a 20% increase is examined for the purpose of sensitivity analysis. This analysis assumes a 20% cost increase relative to the baseline configuration costs during years the advanced technology is implemented (i.e., starting in 1987 for the network HF, simple network HF, and satellite-based configurations and starting in 1992 for the multiple satellite-based configurations). The resulting net total cost savings are shown in Table 9-12. Comparison of Table 9-12 with 9-6 shows that the 20% ATS O&M cost increase causes reductions in net savings of from 26% to 92% for most configurations and more for the simple network HF data link and voice without separation minima reduction. These significant proportional decreases in net savings indicate that O&M costs exercise considerable leverage on the economic analysis results.

TABLE 9-12

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)

20% INCREASE IN PROVIDER ATS O&M COST

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
10	-54.	167.	113.	-40.	-10.	-50.	-94.	157.	63.	ADS, NETWORK HF
11	-86.	150.	65.	-41.	-10.	-51.	-127.	140.	14.	ADS, NETWORK HF, SEP AS DEV-50%
12	-24.	-16.	-41.	-33.	4.	-28.	-57.	-12.	-69.	SIMPLE HF,NO SEP MIN REDUCTION
13	-43.	138.	95.	-33.	4.	-28.	-76.	143.	66.	SIMPLE HF,MIN RED
14	-78.	124.	46.	-34.	4.	-29.	-112.	129.	17.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-64.	167.	103.	-65.	20.	-45.	-129.	186.	57.	ADS, SAT
16	-96.	150.	55.	-66.	20.	-46.	-162.	170.	8.	ADS, SAT, SEP AS DEV-50%
17	-44.	167.	123.	-51.	20.	-31.	-95.	186.	92.	ADS, SAT DL ONLY
18	-76.	150.	74.	-52.	20.	-32.	-128.	170.	42.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-51.	222.	170.	-58.	9.	-49.	-109.	231.	121.	CIS, MULTI SAT
20	-51.	288.	237.	-58.	9.	-49.	-109.	297.	188.	CIS, MULTI SAT, FREE VERT FLIGHT
21	-51.	248.	197.	-58.	9.	-49.	-109.	258.	148.	CIS, MULTI SAT, 60-30 C, MNPS

The net savings shown for the cooperative independent surveillance with multiple satellite improvements (Configurations 19, 20 and 21) should be treated with care based on the following considerations. Because of limited data, the improvement capital and O&M cost estimates for those Configurations were based on analogies with the dependent surveillance satellite system (Configuration 15) rather than on an explicit system design. The operational implementation of Configurations 19, 20 and 21 and concurrent reduced separation minima are assumed to occur in 1995. This date may be optimistically early because of possible technical and operational complexities associated with cooperative independent surveillance. The reduced separation minima are based on concurrent employment of MNPS (Advanced) navigation techniques. Because of future system design uncertainties and resource constraints, implementation requirements for these navigation techniques have not been explicitly addressed. Should additional costs be allocated to oceanic operations because of MNPS (Advanced) requirements, the net cost savings shown in Table 9-12 would be reduced (see Section 9.5).

9.4 Sensitivity Analysis of Fuel Costs

The user fuel costs are based on fuel prices reported for each NAT airport in 1979 and on a 10% annual inflation rate. There is no basis to assume that the 1979 prices are in error, but the inflation rate might vary. A higher than 10% rate would increase the future fuel costs calculated for all configurations and would increase the net cost savings associated with each improvement configuration relative to the baseline configuration. The net savings increase would improve the economic attractiveness of the alternative configurations relative to their preliminary cost estimates, but the significance of the increased attractiveness would depend on the magnitude of fuel cost increase. Alternatively a lower than 10% rate would decrease the economic attractiveness of the alternative configurations. Therefore, the net savings resulting from 8% and 12% inflation rates are calculated as shown in Tables 9-13 and 9-14 respectively.

Comparison of these tables with Table 9-6 shows that the 2% fuel inflation rate decrease to 8% causes net savings reduction of from 0% to 50% for the various configurations; the net savings remain positive for each configuration. The 2% inflation rate increase to 12% furthers net savings by 0% to 70% for the various configurations, indicating that fuel costs exercise significant influence on the economic analysis results.

9.5 MNPS (Advanced) and MNPS (Improved) User Costs

A detailed analysis of design alternatives and costs for navigation system improvements is not a part of this study (as stated in Section 8.2.12). However, there is a prevailing view that the implementation of MNPS (Advanced) could not be accomplished without a significant capital investment on the part of the users (ref. 2). The International Air

TABLE 9-13

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
8% FUEL INFLATION FACTOR

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
2	0.	62.	62.	0.	0.	0.	0.	62.	62.	60-30 COMPOSITE, MNPS
3	0.	62.	62.	0.	0.	0.	0.	62.	62.	60-30 COMPOSITE, MNPS(I)
4	0.	335.	335.	-6.	0.	-6.	-6.	335.	330.	1000 FT OCEANIC
5	-11.	291.	280.	-6.	0.	-6.	-17.	291.	274.	1000 FT OCEANIC + ALTIMETRY
6	0.	456.	456.	-6.	0.	-6.	-6.	455.	450.	1000 FT EVERYWHERE
7	-11.	394.	383.	-6.	0.	-6.	-17.	394.	377.	1000 FT EVERYWHERE + ALTIMETRY
8	-64.	119.	56.	-1.	0.	-1.	-65.	119.	55.	SEP AS DEV, 100% AVIONICS COST
9	-32.	119.	87.	-1.	0.	-1.	-33.	119.	86.	SEP AS DEV, 50% AVIONICS COST
10	-54.	119.	66.	-40.	78.	38.	-94.	197.	103.	ADS, NETWORK HF
11	-86.	103.	17.	-41.	78.	37.	-127.	180.	54.	ADS, NETWORK HF, SEP AS DEV-50%
12	-24.	-18.	-41.	-33.	92.	59.	-57.	75.	18.	SIMPLE HF,NO SEP MIN REDUCTION
13	-43.	96.	52.	-33.	92.	59.	-76.	187.	111.	SIMPLE HF,MIN RED
14	-78.	82.	4.	-34.	92.	58.	-112.	174.	62.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-64.	119.	55.	-65.	107.	42.	-129.	227.	98.	ADS, SAT
16	-96.	103.	7.	-66.	107.	41.	-162.	210.	48.	ADS, SAT, SEP AS DEV-50%
17	-44.	119.	75.	-51.	107.	56.	-95.	227.	132.	ADS, SAT DL ONLY
18	-76.	103.	27.	-52.	107.	55.	-128.	210.	83.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-51.	153.	101.	-58.	75.	16.	-109.	227.	118.	CIS, MULTI SAT
20	-51.	176.	125.	-58.	75.	16.	-109.	251.	141.	CIS, MULTI SAT, 60-30 C, MNPS

TABLE 9-14

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)
12% FUEL INFLATION FACTOR

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
2	0.	101.	101.	0.	0.	0.	0.	101.	101.	60-30 COMPOSITE, MNPS
3	0.	101.	101.	0.	0.	0.	0.	101.	101.	60-30 COMPOSITE, MNPS(I)
4	0.	617.	617.	-6.	0.	-6.	-6.	617.	612.	1000 FT OCEANIC
5	-11.	560.	549.	-6.	0.	-6.	-17.	561.	544.	1000 FT OCEANIC + ALTIMETRY
6	0.	835.	835.	-6.	0.	-6.	-6.	835.	830.	1000 FT EVERYWHERE
7	-11.	757.	746.	-6.	0.	-6.	-17.	757.	740.	1000 FT EVERYWHERE + ALTIMETRY
8	-64.	234.	170.	-1.	0.	-1.	-65.	233.	169.	SEP AS DEV, 100% AVIONICS COST
9	-32.	234.	202.	-1.	0.	-1.	-33.	233.	201.	SEP AS DEV, 50% AVIONICS COST
10	-54.	234.	180.	-40.	78.	38.	-94.	311.	217.	ADS, NETWORK HF
11	-86.	217.	132.	-41.	78.	37.	-127.	295.	168.	ADS, NETWORK HF, SEP AS DEV-50%
12	-24.	-16.	-41.	-33.	92.	59.	-57.	75.	18.	SIMPLE HF,NO SEP MIN REDUCTION
13	-43.	199.	156.	-33.	92.	59.	-76.	291.	215.	SIMPLE HF,MIN RED
14	-78.	185.	107.	-34.	92.	58.	-112.	277.	165.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-64.	234.	170.	-65.	107.	42.	-129.	341.	212.	ADS, SAT
16	-96.	217.	122.	-66.	107.	41.	-162.	324.	163.	ADS, SAT, SEP AS DEV-50%
17	-44.	234.	190.	-51.	107.	56.	-95.	341.	246.	ADS, SAT DL ONLY
18	-76.	217.	141.	-52.	107.	55.	-128.	324.	197.	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-51.	322.	271.	-58.	75.	16.	-109.	397.	287.	CIS, MULTI SAT
20	-51.	353.	302.	-58.	75.	16.	-109.	428.	318.	CIS, MULTI SAT, 60-30 C, MNPS

Transport Association (IATA) has estimated that an additional discounted user capital cost of the order of $50 million, exclusive of user O&M cost, may be required for MNPS (Advanced) based on the following assumptions: (1) reduced separation minima are introduced in 1995; (2) 513 aircraft per year are retrofitted over 3 years from 1992 to 1994; (3) all aircraft entering service in or after 1992 are assumed to have initial fitment of MNPS (Advanced) equipment and thus do not contribute to the cost of its introduction; (4) the estimated cost of dual unit MNPS (Advanced) eqipment is 50 thousand 1979 US$ per aircraft; and (5) an annually compounded inflation rate of 8% and an annually compounded discount rate of 12% apply, which are consistent with the user cost estimation procedures used in this report (ref. 2). As a result, a discounted user capital cost of $50 million may be added to the total costs of those configurations requiring MNPS (Advanced), specifically Configurations 19, 20 and 21. Equivalently, $50 million may be subtracted from the discounted total cost savings (see Tables 9-5 through 9-12) for these three configurations. These savings might further be reduced due to a potential increase in user O&M costs for MNPS (Advanced), but data has not been obtained describing the magnitude of such an increase (if any) relative to the navigation system O&M costs associated with alternative configurations.

In regard to MNPS (Improved), IATA in reference 2 has noted that no user capital cost estimates for on-board navigation equipment have been allocated to meet MNPS (Improved), and has noted that this approach may be reasonable since there is a belief that navigation performance with current on-board systems when properly assessed could provide the required accuracy

9.6 References

1. V. W. Attwooll, "The Cost Benefit of a Single Layer North Atlantic System," UK Civil Aviation Authority, Draft Manuscript (March 1981).

2. International Air Traffic Association, "Review of OASIS First Draft Final Report--OASIS-1," ARC-80/WP-25, Draft Working Paper presented at the 5th meeting of the Aviation Review Committee, Malaga (November, 1980).

10.0 CEP POTENTIAL IMPROVEMENTS AND COSTS

10.1 Introduction

This section describes the extension of four of the potential improvement alternatives discussed in Section 5 to the CEP. The CEP, for the purposes of this report, is the high altitude airspace shown in Figure 10-1 for the Oakland CTA/FIR and the eastern part of the Honolulu CTA/FIR. The four improvements are the network HF data link and voice, satellite data link and voice, separation assurance device, and improved altimetry. The CEP potential improvement implementations are assumed to be coordinated with and extensions of corresponding NAT implementations, although various CEP improvements could be developed and established independently of NAT applications. In addition, the CEP improvements are assumed to be made without regard to operations in adjacent areas in the Pacific. Several adjacent areas are currently served by the Hawaiian HF ground station that services a portion of the CEP. Hence, in the future, it may be desirable to encompass a considerably larger area with the improvements.

10.2 Network HF Data Link and Voice

Extension of HF data link and voice to the CEP can be accomplished by transfer of the system design and costs presented in Section 5.2, subject to adjustment of estimates for reduced traffic and better HF propagation characteristics.

The HF communications in the CEP are approximately 13% of those in the NAT (ref. 1). Two HF ground stations (one in Hawaii and one in California) currently serve the area. Discussions with radio operators and ATC personnel involved in providing CEP HF communications have indicated that HF propagation is more predictable in the CEP than in the NAT. Further, the path diversity available from the two stations appears adequate. Based on the reliability of the existing two stations and other factors, it is assumed that two HF data link stations and one (suitably redundant) master control station could serve the CEP.

The currently assigned frequencies in the CEP are 3467, 5554, 5603, 8875, 8931, 13336, 13312, 17909 KHz. Based on the message loading on the CEP, there appears to be adequate spectrum to support extension of HF data link to the Pacific. The frequencies are not distributed as specified by Working Group B of the Aviation Review Committee, however, and would have to be reallocated to meet those specifications. In addition, if a separate voice family were desired, the equivalent of a new family would have to be allocated to the CEP.

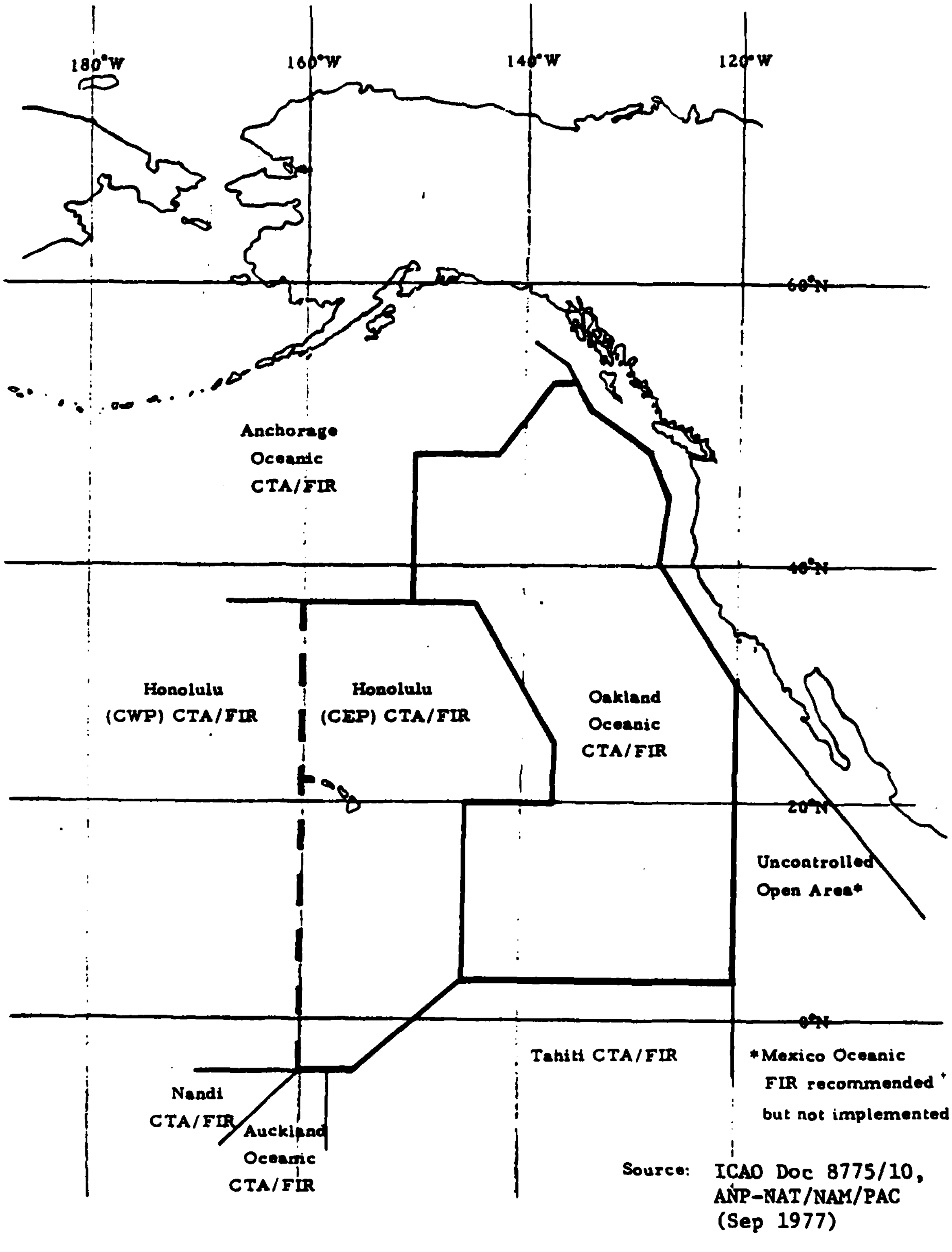


FIGURE 10-1. CEP AIRSPACE

Table 10-1 shows ground station costs estimated for the CEP. Most component requirements are considerably lower than those shown in Table 5-2 for the NAT due to the reduced number of ground stations . Software costs in Table 10-1 are based on modifications to NAT software rather than redevelopment of new software. Table 10-2 shows yearly costs for an HF ground network. It is assumed that all the feasibility studies and development efforts carried out for the NAT would not have to be repeated for the CEP. A sum of $500,000 is alloted in 1983 for CEP feasibility assessment and engineering. Ground station construction is assumed to take place between 1984 and 1987.

Yearly user costs are a function of the fleet that must be equipped exclusively for the CEP. A review of published airline schedules indicates that United Airlines, Western Airlines, Continental, and CP Air serve Hawaii but not the NAT. Almost all service appears to be widebody, although many narrow body aircraft are capable of flying between the North American mainland and the Hawaiian Islands. These airlines are estimated to have approximately 55, 9, 7 and 6 widebody aircraft respectively (ref. 2) for a total of 77 aircraft. This number may be increased to account for other airlines such as Quantas, Air New Zealand, Philippine Airlines, Korean, Air Siam, Thai International, etc. Therefore, the user yearly costs shown in Table 10-3 are based on reequipping 100 aircraft with avionics starting with year 1985.

10.3 Satellite Data Link and Voice

Coverage of the CEP with satellite communications could, in theory, be accomplished with much lower data rates than those postulated for the NAT. Voice requirements, however, dominate the cost of satellite service. Furthermore, a CEP system must be compatible with NAT equipment. To obtain the yearly provider cost estimates shown in Table 10-4, a number of assumptions were made as follows. First, design and development costs would be borne by the NAT. Second, the ground and airborne satellite spares would not be common to the NAT and CEP. Third, tracking, telemetry, and command costs would be the same as for the NAT.

CEP satellite avionics costs are estimated on the same basis as CEP HF data link avionics. Costs are as shown in Table 10-5.

10.4 Separation Assurance Device

Costs considered for the CEP are only for equipping fleets with avionics and maintaining the avionics as shown in Table 10-6 for the case of allocating 100% of the separation assurance device avionics capital costs to CEP operations. This table parallels Table 5-13 with the user costs adjusted according to the discussion in Section 10-2 on HF avionics for the CEP. The retrofit and new equipment capital costs would be half those shown in Table 10-6 for the case of allocating 50% of the avionics capital costs to CEP operations.

Table 10-1

NETWORK HF DATA LINK AND VOICE
GROUND STATION COMPONENT COSTS
FOR THE CEP
(Thousands of 1979 US Dollars)

Component	Number	Unit Cost	Total Cost	Comment
1-kW HF transmitter	5	25	125	
Transmitter multicouplers	5	5	25	
New transmitters, antennas	5	4	20	e.g., ten vertical LPs, ten conical monopolies (TCI 503)
Receivers	10	4	40	e.g., Collins HF 8050
Receiver antennas	5	15	75	e.g., TCI 612
Receiver, multicouplers	5	5	25	
Coaxial cable	10,000 ft	.002	20	
Miscellaneous test equipment	2	50	100	For each site
Land preparation and installation for new antennas.	10	14.5	145	
Land	30 acres	5	150	Assume 1 site would need relocation
Small processors/ data concentration	2	40	80	
Large processors	2	250	500	
Software	1000 lines	.1	100	modifications ftware to NAT software
Terminals with CRT/printer, keyboard	4	10	40	
Modems	4	10	40	
System engineering	1 site	400	400	
Total Fixed Costs			1885	
Satellite link rentals at 10000 per month		$120,000 per year		

Table 10-2

NETWORK HF DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTATION AND
OPERATING THE GROUND
STATION NETWORK FOR THE CEP
(1979 US Dollars)

Year	Development and Ground Station Capital Costs		Equipment Maintenance Costs	One Interconnection Link
1981				
1982				
1983	500,000	(feasibility and engineering)	--	
1984	471,250	(ground station installation)	100,000	
1985	471,250	(ground station installation)	100,000	
1986	471,250	(ground station installation)	100,000	
1987	471,250	(ground station installation)	100,000	120,000
1988			100,000	120,000
1989			100,000	120,000
1990			100,000	120,000
1991			100,000	120,000
1992			100,000	120,000
1993			100,000	120,000
1994			100,000	120,000
1995			100,000	120,000
1996			100,000	120,000
1997			100,000	120,000
1998			100,000	120,000
1999			100,000	120,000
2000			100,000	120,000
2001			100,000	120,000
2002			100,000	120,000
2003			100,000	120,000
2004			100,000	120,000
2005			100,000	120,000
Total	2,385,000			

Table 10-3

NETWORK HF DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION
AND OPERATION FOR THE CEP
(1979 US Dollars)

Year	Avionics Cost(1)	New Aircraft Cost(2)	Total	Yearly User Cost(3)
1985	1,376,000	129,000	1,505,000	145,000
1986	1,376,000	129,000	1,505,000	148,000
1987	1,376,000	129,000	1,505,000	151,000
1988		129,000	129,000	155,000
1989		129,000	129,000	159,000
1990		129,000	129,000	162,000
1991		129,000	129,000	166,000
1992		129,000	129,000	170,000
1993		129,000	129,000	174,000
1994		129,000	129,000	178,000
1995		129,000	129,000	182,000
1996		129,000	129,000	187,000
1997		129,000	129,000	191,000
1998		129,000	129,000	195,000
1999		129,000	129,000	199,000
2000		129,000	129,000	204,000
2001		129,000	129,000	208,000
2002		129,000	129,000	212,000
2003		129,000	129,000	216,000
2004		129,000	129,000	220,000
2005		129,000	129,000	224,000
Total	4,128,000	2,709,000	6,837,0000	

(1) Retrofit 32 aircraft per year for 3 years at $43,000/aircraft.

(2) Added HF costs only for 3 aircraft/year.

(3) One dollar per operating hour calculated as 13% of NAT costs.

Table 10-4

SATELLITE DATA LINK AND VOICE PROVIDER COSTS FOR IMPLEMENTATION AND OPERATING THE GROUND AND SPACE SEGMENT FOR THE CEP (1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	TT&C
1985		326,100		
1986	8,700,000 (2 satellites including ground spare, 1 launch)	326,100	50,000	250,000
1987		326,100	75,000	250,000
1988	5,700,000 (1 sat, 1 launch)	326,100	100,000	250,000
1989			100,000	250,000
1990			100,000	250,000
1991			100,000	250,000
1992			100,000	250,000
1993	5,700,000 (1 sat, 1 launch)		100,000	250,000
1994			100,000	250,000
1995	5,700.000 (1 sat, 1 launch)		100,000	250,000
1996			100,000	250,000
1997			100,000	250,000
1998			100,000	250,000
1999			100,000	250,000
2000	5,700,000 (1 sat, 1 launch)		100,000	250,000
2001			100,000	250,000
2002	5,700,000 (1 sat, 1 launch)		100,000	250,000
2003			100,000	250,000
2004			100,000	250,000
2005			100,000	250,000

Table 10-5

SATELLITE DATA LINK AND VOICE USER COSTS
FOR AVIONICS INSTALLATION AND OPERATION
FOR THE CEP
(1979 US Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost ($1/operating hour)
1985	1,641,600	150,000	1,791,600	145,000
1986	1,641,600	150,000	1,791,600	148,000
1987	1,641,600	150,000	1,791,600	151,000
1988	0	150,000	150,000	155,000
1989	0	150,000	150,000	159,000
1990	0	150,000	150,000	162,000
1991	0	150,000	150,000	166,000
1992	0	150,000	150,000	170,000
1993	0	150,000	150,000	174,000
1994	0	150,000	150,000	178,000
1995	0	150,000	150,000	182,000
1996	0	150,000	150,000	187,000
1997	0	150,000	150,000	191,000
1998	0	150,000	150,000	195,000
1999	0	150,000	150,000	199,000
2000	0	150,000	150,000	204,000
2001	0	150,000	150,000	208,000
2002	0	150,000	150,000	212,000
2003	0	150,000	150,000	216,000
2004	0	150,000	150,000	220,000
2005	0	150,000	150,000	224,000
Total	4,924,800	3,900,000	8,824,800	

(1) 32 aircraft/year at $51,300 per aircraft for 3 years.

(2) 3 new aircraft per year at $50,000 per aircraft.

Table 10-6

AIRBORNE SEPARATION ASSURANCE DEVICE
USER COSTS FOR AVIONICS INSTALLATION
AND OPERATION FOR THE CEP
(1979 US Dollars)

Year	Retrofit Cost (1)	New Aircraft Equipment Cost (2)	Total	Yearly User Cost ($1/operating hour)
1985	1,651,200	146,400	1,797,600	145,000
1986	1,651,200	146,400	1,797,600	148,000
1987	1,651,200	146,400	1,797,600	151,000
1988		146,400	146,400	155,000
1989		146,400	146,400	159,000
1990		146,400	146,400	162,000
1991		146,400	146,400	166,000
1992		146,400	146,400	170,000
1993		146,400	146,400	174,000
1994		146,400	146,400	178,000
1995		146,400	146,400	182,000
1996		146,400	146,400	187,000
1997		146,400	146,400	191,000
1998		146,400	146,400	195,000
1999		146,400	146,400	199,000
2000		146,400	146,400	204,000
2001		146,400	146,400	208,000
2002		146,400	146,400	212,000
2003		146,400	146,400	216,000
2004		146,400	146,400	220,000
2005		146,400	146,400	224,000
Total	4,953,600	3,074,400	8,028,000	

(1) Retrofit 32 aircraft per year at $51,600 per aircraft.

(2) 3 aircraft at $48,800 per aircraft.

10.5 Altimetry Improvements

Table 10-7 shows the yearly cost of extending altimetry improvement to the CEP, based on the Section 5.5 discussion. All provider costs required were allocated to the NAT, so that no significant developmental costs are assigned to the CEP.

10.6 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume V: North Atlantic, Central East Pacific and Caribbean Regions Communication Systems Description, Final Report No. FAA-EM-81-17, V (September 1981).

2. "Commercial Aircraft Fleets," Lockheed-Georgia Company, January 1, 1979.

Table 10-7

ALTIMETRY SYSTEM IMPROVEMENT
USER COSTS FOR AVIONICS
INSTALLATION AND OPERATION
FOR THE CEP (3)
(1979 US Dollars)

Year	Provider Costs	User Calibration and Modification Costs (1)	User New Equipment Costs (2)	User Yearly Maintenance ($50/Aircraft)
1985		320,000	15,000	1,750
1986		320,000	15,000	1,900
1987		320,000	15,000	2,050
1988			15,000	2,200
1989			15,000	2,350
1990			15,000	2,500
1991			15,000	2,650
1992			15,000	2,800
1993			15,000	2,950
1994			15,000	3,100
1995			15,000	3,250
1996			15,000	3,400
1997			15,000	3,550
1998			15,000	3,700
1999			15,000	3,850
2000			15,000	4,000
2001			15,000	4,150
2002			15,000	4,300
2003			15,000	4,450
2004			15,000	4,600
2005			15,000	4,750
Total		960,000	390,000	

(1) 32 aircraft per year at $10,000 per aircraft.

(2) 3 new aircraft per year at $5,000 per aircraft.

(3) Sample costs for demonstration purposes only.

11.0 CEP USER FLIGHT COSTS

11.1 Introduction

The user flight O&M costs corresponding to a variety of assumed separation minima in the CEP are estimated in this section. Similar to the cost calculation procedure described for the NAT in Section 6, the user flight costs are the FCM-calculated aircraft fuel, crew, and maintenance expenditures, excluding the avionics improvement annual operating costs described in the preceding section. Data presented in this section are extracted in part from a companion document (ref. 1) describing the application of the FCM to the CEP and are supported by additional information presented in Appendix E.

11.2 Flight Cost Model Application

The FCM was used to simulate the operation of the present CEP ATS system and several other system operating alternatives (representing alternative separation minima sets) on a representative July (peak) day and a representative November (off-peak) day in 1979, and with traffic forecasts for 1984 and 2005 (ref. 3). The July sample day operation in each of the three sample years was simulated for the various alternatives. The November sample day in each year was simulated only for the 1979 base case system (100-50 nmi/15 min/2000 ft separation minima) for comparison purposes. (Note: As in the case of NAT analysis, the non-Mach number technique separation minimum is assumed to be 5 min greater than the nominal separation indicated.)

The inputs and operation of the FCM for the CEP application are analogous to those described for the NAT application in Section 6 of this report. The traffic distribution for the CEP is shown in Table 11-1, which shows a 195% increase in daily costed traffic between 1979 (156 flights) and 2005 (459 aircraft) and a 171% increase in total traffic over the same time period (479 versus 177 flights). All flights (costed and non-costed) are included in the simulation to represent actual traffic congestion situations.

11.3 Overall Costs--July Sample Day

The FCM ideal, planned and actual cost results for the July CEP sample day are summarized in Table 11-2, which shows the estimated daily fuel, crew, and maintenance cost totals for all costed aircraft for each system operating alternative in each sample year. The ideal flight mode results show that the theoretical minimum daily flight cost regardless of system operating alternative is US$ 2.8 million in 1979, and increases to $4.1 million in 1984 and $11.1 million in 2005. The increase is due

Table 11-1

CEP TRAFFIC COMPOSITION, JULY SAMPLE DAY

	Traffic Loading		
	1979	1984	2005
Total Number of Flights	177	230	479
Air Carrier	89%	91%	96%
Military	11%	9%	4%
Number of Air Carrier Flights	157	210	459
Costed Air Carrier	99%	100%	100%
Number of Costed Air Carrier Flights	156	210	459
Wide Body Costed Air Carrier	81%	95%	100%

The traffic loading data is based on growth factors developed by the traffic forecasting workshop convened by the Aviation Review Committee and documented in reference 3.

Table 11-2

CEP FCM DAILY FLIGHT COSTS, JULY SAMPLE DAY

Year	Ideal Flight Operating Mode	Daily Cost by System Operating Alternative† 100-50 NMI 15 Min 2000 Ft	50 NMI 15 Min 2000 Ft	50 NMI 10 Min 2000 Ft	25 NMI 10 Min 2000 Ft	25 NMI 5 Min 2000 Ft	50 NMI 15 Min 1000 Ft	50 NMI 10 Min 1000 Ft	50 NMI 10 Min 1000 Ft*
		Daily Flight Cost (1979 $000)							
1979	Ideal	2784	2784	2784	2784	2784	2784	2784	2784
	Planned	2805	2806	2806	2808	2808	2796	2796	2799
	Actual	2816	2816	2814	2817	2816	2807	2806	2808
1984	Ideal	4133	4133	4133	4133	4133	4133	4133	4133
	Planned	4165	4166	4166	4165	4165	4151	4151	4158
	Actual	4183	4182	4177	4175	4173	4163	4162	4169
2005	Ideal	11055	11055	11055	11055	11055	11055	11055	11055
	Planned	11144	11145	11145	11142	11142	11102	11102	11122
	Actual	11209	11201	11190	11180	11172	11135	11130	11155
		Daily Average Flight Cost (1979 $000 per Flight)							
1979	Ideal	17.85	17.85	17.85	17.85	17.85	17.85	17.85	17.85
	Planned	17.98	17.99	17.99	18.00	18.00	17.92	17.92	17.94
	Actual	18.05	18.05	18.04	18.06	18.05	17.99	17.99	18.00
1984	Ideal	19.68	19.68	19.68	19.68	19.68	19.68	19.68	19.68
	Planned	19.83	19.84	19.84	19.83	19.83	19.77	19.77	19.80
	Actual	19.92	19.91	19.89	19.88	19.87	19.82	19.82	19.85
2005	Ideal	24.08	24.08	24.08	24.08	24.08	24.08	24.08	24.08
	Planned	24.28	24.28	24.28	24.27	24.27	24.19	24.19	24.23
	Actual	24.42	24.40	24.38	24.36	24.34	24.26	24.25	24.30

*1000 ft vertical separation in CEP oceanic airspace only; 2000 ft elsewhere.

†Constant 1979 $ U.S. excluding inflation and discount rate.

to the 195 % increase in costed traffic over the 26-year study period, as well as a change in fleet mix. The wide body aircraft proportion of costed traffic is projected to increase from 81% to 100% over the 1979 to 2005 time period and causes the ideal daily flight cost to increase from $17,850 to $24,080 per flight over the same period.

11.4 Theoretical Cost Penalties--July Sample Day

The cost differences between the ideal cost and the actual costs represent the maximum possible cost penalties that could theoretically be avoided by any system improvements. These cost penalties for the July sample day are shown in Table 11-3, which presents the total cost difference between planned and ideal costs and between actual and ideal costs. For comparison purposes, the costs shown are not inflated and not discounted.

The Table 11-3 data indicate that the potential daily cost differences associated with planned costs are a majority of the total flight cost penalty. For example, the data for the 50 nmi/10 min/2000 ft system in 1984 show that the estimated planned daily cost difference ($33,000) accounts for 75% of the difference ($44,000) between ideal and actual daily costs. The planned cost proportion of the actual daily cost penalty ranges from 64% for the 100-50 nmi/15 min/2000 ft to 80% for the 25 nmi/5 min/2000 ft system in 1984. Note that the lowest cost penalty in each year is associated with the 1000 ft vertical separation minimum.

11.5 System Cost Comparison--July Sample Day

The impact of separation minima reduction is shown in Table 11-4, which presents the difference in daily flight costs between the base case 100-50 nmi/15 min/2000 ft system and each of the separation minima alternatives for the July sample day. The planned daily flight cost reductions for each of the separation minima alternatives for the July sample day. The planned daily flight cost reductions for each of the seven alternatives are calculated relative to the base case system planned cost; the actual daily cost reductions are calculated similarly.

The planned cost reductions shown in Table 11-4 reflect the impact of separation minima reductions. However, planned costs show very small increase (i.e., $1 thousand) from implementation of the 50 nmi lateral spacing (e.g., see 50 nmi/10 min/2000 ft planned costs in Table 11-4), perhaps due to loss of even flight levels on the previously composite tracks. For example, aircraft that could previously have flown at FL360 may have been forced down to FL350, which would be slightly more costly. A similar increase in planned costs is seen in the 25 nmi lateral separation scenario in the earlier years, which might be attributable to flight direction assignments. All but two tracks are unidirectional, and insertion of new tracks requires half of the unidirectional tracks to change direction. Thus, some preferred routings might no longer be

Table 11-3

CEP FCM DAILY FLIGHT COSTS RELATIVE TO IDEAL MODE, JULY SAMPLE DAY

Year	Flight Operating Mode	Relative Daily Cost by System Operating Alternative: 100-50 NMI 15 Min 2000 Ft	50 NMI 15 min 2000 Ft	50 NMI 10 Min 2000 Ft	25 NMI 10 Min 2000 Ft	25 NMI 5 Min 2000 Ft	50 NMI 15 Min 1000 Ft	50 NMI 10 Min 1000 Ft	50 NMI 10 Min 1000 Ft*
		Daily Flight Cost Difference Relative to Free Search Mode in Year Indicated (1979 $000)†							
1979	Planned	21	22	22	24	24	12	12	15
	Actual	32	32	30	33	32	23	22	24
1984	Planned	32	33	33	32	32	18	18	25
	Actual	50	49	44	42	40	30	29	36
2005	Planned	89	90	90	87	87	47	47	67
	Actual	154	146	135	125	118	80	75	100
		Daily Average Flight Cost Difference Relative to Free Search Mode in Year Indicated (1979 $000 per Flight)†							
1979	Planned	0.13	0.14	0.14	0.15	0.15	0.07	0.07	0.09
	Actual	0.20	0.20	0.19	0.21	0.20	0.14	0.14	0.15
1984	Planned	0.15	0.16	0.16	0.15	0.15	0.09	0.09	0.12
	Actual	0.24	0.23	0.21	0.20	0.19	0.14	0.14	0.17
2005	Planned	0.20	0.20	0.20	0.19	0.19	0.11	0.11	0.15
	Actual	0.34	0.32	0.30	0.28	0.26	0.18	0.17	0.22

*1000 ft vertical separation in CEP oceanic airspace only; 2000 ft elsewhere.

†Constant 1979 $ U.S. excluding inflation and discount rate.

Table 11-4

CEP FCM DAILY COSTS RELATIVE TO 50-100/15/2000 SYSTEM, JULY SAMPLE DAY IN CEP

Year	Flight Operating Mode	Relative Daily Cost by System Operating Alternative						
		50 NMI 15 Min 2000 Ft	50 NMI 10 Min 2000 Ft	25 NMI 10 Min 2000 Ft	25 NMI 5 Min 2000 Ft	50 NMI 15 Min 1000 Ft	50 NMI 10 Min 1000 Ft	50 NMI 10 Min 1000 Ft*
		Daily Flight Cost Difference Relative to 50-100/15/2000 System in Year Indicated (1979 $000)†						
1979	Planned	(1)	(1)	(3)	(3)	9	9	6
	Actual	-	2	(1)	-	9	10	8
1984	Planned	(1)	(1)	-	-	14	14	7
	Actual	1	6	8	10	20	21	14
2005	Planned	(1)	(1)	2	2	42	42	22
	Actual	8	19	29	37	74	79	54
		Daily Average Flight Cost Difference Relative to 50-100/15/2000 System in Year Indicated (1979 $000)†						
1979	Planned	(0.01)	(0.01)	(0.02)	(0.02)	0.06	0.06	0.04
	Actual	-	0.01	(0.01)	-	0.06	0.06	0.05
1984	Planned	(0.01)	(0.01)	-	-	0.06	0.06	0.03
	Actual	0.01	0.03	0.04	0.05	0.10	0.10	0.07
2005	Planned	-	-	0.01	0.01	0.09	0.09	0.05
	Actual	0.02	0.04	0.06	0.08	0.16	0.17	0.12

*1000 ft vertical separation in CEP oceanic airspace only; 2000 ft elsewhere.

†Constant 1979 $ U.S. excluding inflation and discount rate.

( ) indicates greater relative cost.

available. (Note that approximately half of the preferred routings would be lost regardless of which way the tracks are set up, i.e., eastbound-westbound-eastbound, or westbound-eastbound-westbound. Some aircraft might then be forced to fly as much as 25nmi away from previously preferred tracks. The decreased lateral spacing produces gains in terms of reduced conflict and diversion, resulting in $8 thousand and $29 thousand daily actual cost savings in 1984 and 2005, respectively, for the 25 nmi/10 min/2000 ft operation. Further relaxation of constraints by reducing longitudinal separation to 5 minutes in the 25nmi system produces even greater savings.

The most dramatic reductions in planned and actual costs derive from the halving of the vertical separation minimum to 1000 ft. When the 50 nmi system with 10 min longitudinal separation is reduced to 1000 ft in the CEP oceanic area in 2005, savings over the baseline increase from $19 thousand to $54 thousand. When the 1000 ft. separation criterion is applied in domestic and oceanic airspace, the savings in 2005 increase to $79 thousand daily. This large increase in the later years is due in part to a proportionally higher traffic growth forecast for flights which spend significant flight time in non-CEP airspace versus CEP-oriented flights (such as ORS flights between Hawaii and California).

As in the case of the NAT, the actual daily cost savings achievable by halving vertical separations throughout are greater than twice those achievable by halving lateral separaions. In all cases where lateral and vertical separations are fixed, some cost savings are obtained by longitudinal minimum reduction. However, the relative impacts of longitudinal reductions are less as lateral and vertical minima are reduced. For example, a reduction of 5 min in the longitudinal minima produces 138%, 28%, and 7% increases in savings in regard to daily actual flight costs in the 50 nmi and 2000 ft, 25 nmi and 2000 ft, and 50 nmi and 1000 ft systems in 2005, respectively.

11.6. July and November Daily Cost Comparison

The FCM was applied to a November sample using the present 100-50nmi/15min/2000ft as a basis for comparing cost magnitudes by year with those of the July sample day. The number of costed flights in the November sample day for 1979 is 87 percent of that in the July sample day, and the daily cost summed over all flights is correspondingly less in November than in July as shown in Table 11-5. The November 1979 sample day flight cost is 92 percent of the July 1979 daily cost, but the daily average flight cost is greater in the November than the July 1979 sample day. This increased cost per aircraft in November 1979 versus July 1979 might be due to a slight difference in fleet composition and to differences in weather patterns; widebody aircraft comprise 85% of the November sample day costed traffic as opposed to 81% in July. The progressive increase in average flight costs from 1979 to 1984 to 2005 arises from more significant congestion penalties, resulting from heavier traffic loadings.

Table 11-5

FCM COST COMPARISONS FOR NOVEMBER AND JULY SAMPLE DAY
BASED ON 50-100/15/2000 SYSTEM OPERATION

Sample Day		Number Of Costed Flights	Daily Flight Cost (1979 $000)	Daily Average Flight Cost (1979 $000 Per Flight)
July	1979	156	2784	17.85
November	1979	135	2564	18.99
July	1984	210	4183	19.92
November	1984	183	3530	19.29
July	2005	459	11209	24.42
November	2005	390	9123	23.39

11.7. Annual Flight O&M Costs

The actual average annual flight costs are estimated in terms of both fuel cost and crew and maintenance cost, as shown in Table 11-6. These data are the actual cost estimates rather than the ideal or planned cost estimates discussed previously.

The annual cost data in Table 11-6 was developed by calculating the simple arithmetic average of the FCM-derived actual daily cost data for the July and November sample days for the indicated year for the 1979 base case system, and multiplying each of these average days by 365. Annual costs for the other systems were based on extrapolations of the November daily costs.

The data in Table 11-6 shows that the total annual user flight costs are large, ranging from almost $1000 million in 1979 to over $3700 million in 2005. Cost differences in any single year between the system alternatives account for a small percentage of the total costs, but these differences are quite large and therefore very important to the users. For example, an annual cost difference of about $3 million is shown in Table 11-6 between the 50 nmi/10 min/2000 ft and 50 nmi/10 min/1000 ft operation in 1984.

The annual flight O&M costs for each year in the 1979 to 2005 study period for each separation minima operating alternative were estimated by interpolation from the data presented in Table 11-6 using interpolation procedures similar to those described for the NAT. A special FCM simulation of the base case 100-50 nmi/15 min/2000 ft operation for the July 1995 sample day augmented the estimation process. The resulting estimated annual fuel and crew and maintenance costs are shown in Table 11-7, which lists the flight costs that would be incurred if each system were in operation in the indicated year.

Table 11-7 also includes cost data for two separation minima alternatives (i.e., 50-25 nmi/10 min/2000 ft and 15 nmi/2 min/2000 ft) that were not simulated by the FCM. These non-FCM cost data were estimated by interpolation or, as warranted, extrapolation of the cost data derived from eight cases analyzed by the FCM. The estimation procedures are described in Appendix E. The additional separation minima alternatives shown in Table 11-7 were selected because they were considered necessary for the cost analysis of the potential system improvements or for general interest and future reference as necessary.

The data in 11-7 will be used subsequently in Section 13 to compare potential improvements costs.

Table 11-6

CEP ANNUAL USER FLIGHT COSTS BASED ON WEIGHTED AVERAGE AND EXTRAPOLATION OF FCM ANALYSIS OF JULY 1979,84 AND 2005 AND NOVEMBER 1979 SAMPLE DAYS

System Operating Alternative	Annual Flight O&M Cost by Year (1979 US $ Millions)								
	1979			1984			2005		
	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
100-50 nmi/15 min/2000 ft	628.90	352.96	981.86	909.03	502.24	1411.27	2425.61	1291.01	3716.62
50 nmi/15 min/2000 ft	628.90	352.96	981.86	908.67	501.88	1410.55	2425.24	1290.09	3715.33
50 nmi/10 min/2000 ft	628.17	352.96	981.13	907.39	502.24	1409.63	2421.96	1289.73	3711.69
25 nmi/10 min/2000 ft	628.17	353.32	981.49	905.93	502.61	1408.54	2417.76	1290.64	3708.40
25 nmi/5 min/2000 ft	627.44	353.69	981.13	905.38	502.61	1407.99	2414.66	1290.09	3704.75
50 nmi/15 min/1000 ft	623.97	354.42	978.39	903.01	504.25	1407.26	2405.17	1293.74	3698.17
50 nmi/10 min/1000 ft	623.79	354.42	978.21	902.28	504.25	1406.53	2403.89	1293.74	3696.89
50 nmi/10 min/1000* ft	624.73	354.36	979.09	902.67	503.61	1406.28	2406.81	1292.35	3699.16

*1000 ft vertical separation in CEP oceanic airspace only, 2000 ft elsewhere.

Table 11-7

CEP ANNUAL USER FLIGHT O&M COST ESTIMATES
(Millions of 1979 US Dollars)

	100-50 nmi/15 min/2000 ft			50 nmi/15 min/2000 ft			50 nmi/10 min/2000 ft		
Year	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	628.90	352.96	981.86	628.90	342.96	981.86	628.17	352.96	981.13
1980	676.99	378.76	1055.75	676.93	378.70	1055.63	676.11	378.76	1054.87
1981	728.75	406.44	1135.19	728.64	406.33	1134.97	727.72	406.44	1134.16
1982	784.48	436.15	1220.63	784.29	435.96	1220.25	783.26	436.15	1219.41
1983	844.46	468.03	1312.49	844.19	467.76	1311.95	843.04	468.02	1311.07
1984	909.03	502.24	1411.27	908.67	551.88	1410.55	907.39	502.24	1409.63
1985	958.44	528.25	1486.59	958.08	527.77	1485.85	956.73	528.13	1484.86
1986	1010.54	555.40	1565.94	1010.17	554.99	1565.16	1008.76	555.36	1564.12
1987	1065.46	584.06	1649.52	1065.09	583.62	1648.71	1063.61	583.99	1647.60
1988	1123.38	614.19	1737.57	1123.00	613.72	1736.72	1121.45	614.10	1735.55
1989	1184.44	645.88	1830.32	1184.06	645.38	1829.44	1182.43	645.75	1828.18
1990	1248.82	679.20	1928.02	1248.44	678.67	1927.11	1246.73	679.04	1925.77
1991	1316.70	714.24	2030.94	1316.32	713.68	2030.00	1314.52	714.05	2028.57
1992	1288.27	751.09	2139.36	1387.89	750.49	2138.38	1386.00	750.86	2136.86
1993	1463.72	789.85	2253.57	1463.35	789.20	2252.55	1461.37	789.57	2250.94
1994	1543.29	830.60	2373.89	1542.92	829.91	2372.83	1540.83	830.28	2371.11
1995	1627.17	873.45	2500.62	1626.81	872.72	2499.53	1624.62	873.08	2497.70
1996	1693.45	908.25	2601.70	1693.08	907.51	2600.59	1690.80	907.82	2498.62
1997	1762.42	944.44	2706.86	1762.06	943.68	2705.74	1759.68	943.94	2703.62
1998	1834.21	982.08	2816.29	1833.84	981.29	2815.13	2831.37	981.49	2812.86
1999	1908.92	1021.21	2930.13	1908.55	1020.41	2928.96	1905.98	1020.54	2926.52
2000	1986.68	1061.90	3048.58	1986.30	1061.08	3047.38	1983.62	1061.15	3044.77
2001	2067.60	1104.21	3171.81	2067.22	1103.37	3170.59	2064.43	1103.37	3167.80
2002	2151.81	1148.21	3300.02	2151.44	1147.35	3298.79	2148.53	1147.27	3295.80
2003	2239.46	1193.96	3433.42	2239.08	1193.08	3432.17	2236.06	1192.92	3428.98
2004	2330.68	1241.54	3572.22	2330.31	1240.64	3570.95	2327.16	1240.38	3567.54
2005	2425.61	1291.01	3716.62	2425.24	1290.09	3715.33	2421.96	1289.73	3711.69

Table 11-7 (Continued)

Year	25 nmi/10 min/2000 ft Fuel	25 nmi/10 min/2000 ft Crew & Maint.	25 nmi/10 min/2000 ft Total	25 nmi/5 min/2000 ft Fuel	25 nmi/5 min/2000 ft Crew & Maint.	25 nmi/5 min/2000 ft Total	50 nmi/15 min/1000 ft Fuel	50 nmi/15 min/1000 ft Crew & Maint.	50 nmi/15 min/1000 ft Total
1979	628.17	353.32	981.49	627.44	353.69	981.13	623.97	354.42	978.39
1980	675.90	379.12	1055.02	625.19	379.44	1054.63	671.85	380.32	1052.17
1981	727.25	406.81	1134.06	726.57	407.07	1133.64	723.39	408.10	1131.49
1982	782.51	436.52	1219.03	781.86	436.70	1218.56	778.90	437.92	1216.82
1983	841.96	468.40	1310.36	841.35	468.50	1309.85	838.66	469.92	1308.58
1984	905.93	502.61	1408.54	905.38	502.61	1407.99	903.01	504.25	1407.26
1985	955.19	528.53	1483.72	954.57	528.51	1483.08	951.99	530.22	1482.21
1986	1007.12	555.78	1562.90	1006.43	555.74	1562.17	1003.62	557.54	1561.16
1987	1061.88	584.44	1646.32	1061.11	584.37	1645.48	1058.05	586.25	1644.30
1988	1119.61	614.57	1734.18	1118.77	614.48	1733.25	1115.44	616.45	1731.89
1989	1180.48	646.26	1826.74	1179.55	646.14	1825.69	1175.93	648.21	1824.14
1990	1244.67	679.58	1924.25	1243.64	679.43	1923.07	1239.71	682.59	1921.30
1991	1312.34	714.62	2026.96	1311.21	714.44	2025.65	1306.95	716.70	2023.65
1992	1383.69	751.47	2135.16	1382.45	751.25	2133.70	1377.83	753.62	2131.45
1993	1458.92	790.22	2249.14	1457.56	789.95	2247.51	1452.56	792.44	2245.00
1994	1538.25	830.96	2369.21	1536.75	830.65	2367.40	1531.36	833.26	2364.61
1995	1621.88	873.81	2495.69	1620.24	873.45	2493.69	1614.40	876.18	2490.58
1996	1687.94	908.56	2596.50	1686.19	908.19	2594.38	1680.06	911.00	2591.06
1997	2756.70	944.70	2701.40	1754.83	944.31	2699.14	1748.39	947.21	2695.60
1998	1828.26	982.28	2810.54	1826.26	981.87	2808.13	1819.50	984.85	2804.35
1999	1902.73	1021.34	2924.07	1900.60	1020.92	2921.52	1893.50	1023.99	2917.49
2000	1980.23	1061.97	3042.20	1977.96	1061.52	3039.48	1970.51	1064.68	3035.19
2001	2060.89	1104.21	3165.10	2058.47	1103.74	3162.21	2050.65	1106.99	3157.64
2002	2144.84	1148.12	3292.96	2142.26	1147.64	3289.90	2134.05	1150.99	3285.04
2003	2232.21	1193.79	3426.00	2229.47	1193.28	3422.75	2220.85	1196.73	3417.58
2004	2323.13	1241.27	3564.40	2320.22	1240.74	3560.96	2311.17	1244.29	3555.46
2005	2417.76	1290.64	3708.40	2414.66	1290.09	3704.75	2405.17	1293.74	3698.91

Table 11-7 (Continued)

Year	50 nmi/10 min/1000 ft			50 nmi/10 min/1000* ft			15 nmi/2 min/2000 ft		
	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	623.79	354.42	978.21	624.73	354.36	979.09	627.44	352.96	980.40
1980	671.58	380.32	1051.90	672.45	380.17	1052.62	674.98	378.81	1053.79
1981	723.04	408.10	1131.15	723.81	407.85	1131.66	726.13	306.44	1132.68
1982	778.43	437.92	1216.36	779.10	437.56	1216.66	781.15	436.33	1217.48
1983	838.07	469.92	1307.99	838.61	469.42	1308.03	840.34	468.28	1308.62
1984	902.28	504.25	1406.53	902.67	503.61	1406.28	904.01	502.58	1406.59
1985	951.24	530.22	1481.46	951.82	529.52	1481.34	953.16	528.48	1481.64
1986	1002.85	557.54	1560.39	1003.64	556.76	1560.40	1004.97	555.71	1560.68
1987	1056.26	586.25	1643.51	1058.28	585.40	1643.68	1059.61	584.34	1643.95
1988	1114.63	616.45	1731.08	1115.90	615.51	1731.41	1117.21	614.45	1731.66
1989	1175.11	648.21	1823.32	1176.66	647.17	1823.83	1177.94	646.12	1824.06
1990	1238.87	681.59	1920.46	1240.72	680.46	1921.18	1241.98	679.41	1921.39
1991	1306.09	716.70	2022.79	1308.27	715.47	2023.74	1309.50	714.42	2023.92
1992	1376.96	753.62	2130.58	1379.50	752.27	2131.77	1380.69	751.23	2131.92
1993	1451.67	792.44	2244.11	1454.61	790.97	2245.58	2455.75	789.94	2245.69
1994	1530.44	833.26	2363.70	1533.81	831.66	2365.47	1534.89	830.65	2365.54
1995	1613.48	876.18	2489.66	1617.32	874.44	2491.76	1618.33	873.45	2491.78
1996	1679.11	911.00	2590.11	1682.91	909.27	2592.18	1684.13	908.18	2592.31
1997	1747.41	947.21	2694.62	1751.16	945.50	2696.66	1752.61	944.28	2696.89
1998	1818.48	984.85	2803.34	1822.17	983.16	2805.33	1823.87	981.83	2805.70
1999	1892.45	1023.99	2916.44	1896.07	1022.33	2918.40	1898.02	1020.87	2918.88
2000	1969.42	1064.68	3034.11	1972.96	1063.05	3036.01	1975.20	1061.45	3036.65
2001	2049.53	1106.99	3156.53	2052.97	1105.40	3158.37	2055.51	1103.65	3159.16
2002	2132.89	1150.99	3283.89	2136.23	1149.44	3285.67	2139.08	1147.53	3286.61
2003	2219.65	1196.73	3416.38	2222.86	1195.23	3418.09	2226.06	1193.15	3419.21
2004	2309.93	1244.29	3554.23	2313.01	1242.84	3555.85	2316.57	1240.59	3557.16
2005	2403.89	1293.74	3697.63	2406.81	1292.35	3699.16	2410.76	1289.91	3700.67

Table 11-7 (Continued)

CEP ANNUAL USER FLIGHT O&M COST ESTIMATES
(Millions of 1979 US Dollars)

	100-50 nmi/14 min/2000 ft			50 nmi/15 min/2000 ft			50 nmi/10 min/2000 ft		
Year	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	628.90	352.96	981.86	628.90	342.96	981.86	628.17	352.96	981.13
1980	676.99	378.76	1055.75	676.93	378.70	1055.63	676.11	378.76	1054.87
1981	728.75	406.44	1135.19	728.64	406.33	1134.97	727.72	406.44	1134.16
1982	784.48	436.15	1220.63	784.29	435.96	1220.25	783.26	436.15	1219.41
1983	844.46	468.03	1312.49	844.19	467.76	1311.95	843.04	468.02	1311.07
1984	909.03	502.24	1411.27	908.67	501.88	1410.55	907.39	502.24	1409.63
1985	958.44	528.25	1486.59	958.08	527.77	1485.85	956.73	528.13	1484.86
1986	1010.54	555.40	1565.94	1010.17	554.99	1565.16	1008.76	555.36	1564.12
1987	1065.46	584.06	1649.52	1065.09	583.62	1648.71	1063.61	583.99	1647.60
1988	1123.38	614.19	1737.57	1123.00	613.72	1736.72	1121.45	614.10	1735.55
1989	1184.44	645.88	1830.32	1184.06	645.38	1829.44	1182.43	645.75	1828.18
1990	1248.82	679.20	1928.02	1248.44	678.67	1927.11	1246.73	679.04	1925.77
1991	1316.70	714.24	2030.94	1316.32	713.68	2030.00	1314.52	714.05	2028.57
1992	1288.27	751.09	2139.36	1387.89	750.49	2138.38	1386.00	750.86	2136.86
1993	1463.72	789.85	2253.57	1463.35	789.20	2252.55	1461.37	789.57	2250.94
1994	1543.29	830.60	2373.89	1542.92	829.91	2372.83	1540.83	830.28	2371.11
1995	1627.17	873.45	2500.62	1626.81	872.72	2499.53	1624.62	873.08	2497.70
1996	1693.45	908.25	2601.70	1693.08	907.51	2600.59	1690.80	907.82	2498.62
1997	1762.42	944.44	2706.86	1762.06	943.68	2705.74	1759.68	943.94	2703.62
1998	1834.21	982.08	2816.29	1833.84	981.29	2815.13	2831.37	981.49	2812.86
1999	1908.92	1021.21	2930.13	1908.55	1020.41	2928.96	1905.98	1020.54	2926.52
2000	1986.68	1061.90	3048.58	1986.30	1061.08	3047.38	1983.62	1061.15	3044.77
2001	2067.60	1104.21	3171.81	2067.22	1103.37	3170.59	2064.43	1103.37	3167.80
2002	2151.81	1148.21	3300.02	2151.44	1147.35	3298.79	2148.53	1147.27	3295.80
2003	2239.46	1193.96	3433.42	2239.08	1193.08	3432.17	2236.06	1192.92	3428.98
2004	2330.68	1241.54	3572.22	2330.31	1240.64	3570.95	2327.16	1240.38	3567.54
2005	2425.61	1291.01	3716.62	2425.24	1290.09	3715.33	2421.96	1289.73	3711.69

Table 11-7 (Continued)

	25 nmi/10 min/2000 ft			25 nmi/5 min/2000 ft			50 nmi/15 min/1000 ft		
Year	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	628.17	353.32	981.49	627.44	353.69	981.13	623.97	354.42	978.39
1980	675.90	379.12	1055.02	625.19	379.44	1054.63	671.85	380.32	1052.17
1981	727.25	406.81	1134.06	726.57	407.07	1133.64	723.39	408.10	1131.49
1982	782.51	436.52	1219.03	781.86	436.70	1218.56	778.90	437.92	1216.82
1983	841.96	468.40	1310.36	841.35	468.50	1309.85	838.66	469.92	1308.58
1984	905.93	502.61	1408.54	905.38	502.61	1407.99	903.01	504.25	1407.26
1985	955.19	528.53	1483.72	954.57	528.51	1483.08	951.99	530.22	1482.21
1986	1007.12	555.78	1562.90	1006.43	555.74	1562.17	1003.62	557.54	1561.16
1987	1061.88	584.44	1646.32	1061.11	584.37	1645.48	1058.05	586.25	1644.30
1988	1119.61	614.57	1734.18	1118.77	614.48	1733.25	1115.44	616.45	1731.89
1989	1180.48	646.26	1826.74	1179.55	646.14	1825.69	1175.93	648.21	1824.14
1990	1244.67	679.58	1924.25	1243.64	679.43	1923.07	1239.71	682.59	1921.30
1991	1312.34	714.62	2026.96	1311.21	714.44	2025.65	1306.95	716.70	2023.65
1992	1383.69	751.47	2135.16	1382.45	751.25	2133.70	1377.83	753.62	2131.45
1993	1458.92	790.22	2249.14	1457.56	789.95	2247.51	1452.56	792.44	2245.00
1994	1538.25	830.96	2369.21	1536.75	830.65	2367.40	1531.36	833.26	2364.61
1995	1621.88	873.81	2495.69	1620.24	873.45	2493.69	1614.40	876.18	2490.58
1996	1687.94	908.56	2596.50	1686.19	908.19	2594.38	1680.06	911.00	2591.06
1997	2756.70	944.70	2701.40	1754.83	944.31	2699.14	1748.39	947.21	2695.60
1998	1828.26	982.28	2810.54	1826.26	981.87	2808.13	1819.50	984.85	2804.35
1999	1902.73	1021.34	2924.07	1900.60	1020.92	2921.52	1893.50	1023.99	2917.49
2000	1980.23	1061.97	3042.20	1977.96	1061.52	3039.48	1970.51	1064.68	3035.19
2001	2060.89	1104.21	3165.10	2058.47	1103.74	3162.21	2050.65	1106.99	3157.64
2002	2144.84	1148.12	3292.96	2142.26	1147.64	3289.90	2134.05	1150.99	3285.04
2003	2232.21	1193.79	3426.00	2229.47	1193.28	3422.75	2220.85	1196.73	3417.58
2004	2323.13	1241.27	3564.40	2320.22	1240.74	3560.96	2311.17	1244.29	3555.46
2005	2417.76	1290.64	3708.40	2414.66	1290.09	3704.75	2405.17	1293.74	3698.91

Table 11-7 (Continued)

	50 nmi/10 min/1000 ft			50 nmi/10 min/1000* ft			15 nmi/2 min/2000 ft		
Year	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total	Fuel	Crew & Maint.	Total
1979	623.79	354.42	978.21	624.73	354.36	979.09	627.44	352.96	980.40
1980	671.58	380.32	1051.90	672.45	380.17	1052.62	674.98	378.81	1053.79
1981	723.04	408.10	1131.15	723.81	407.85	1131.66	726.13	306.44	1132.68
1982	778.43	437.92	1216.36	779.10	437.56	1216.66	781.15	436.33	1217.48
1983	838.07	469.92	1307.99	838.61	469.42	1308.03	840.34	468.28	1308.62
1984	902.28	504.25	1406.53	902.67	503.61	1406.28	904.01	502.58	1406.59
1985	951.24	530.22	1481.46	951.82	529.52	1481.34	953.16	528.48	1481.64
1986	1002.85	557.54	1560.39	1003.64	556.76	1560.40	1004.97	555.71	1560.68
1987	1056.26	586.25	1643.51	1058.28	585.40	1643.68	1059.61	584.34	1643.95
1988	1114.63	616.45	1731.08	1115.90	615.51	1731.41	1117.21	614.45	1731.66
1989	1175.11	648.21	1823.32	1176.66	647.17	1823.83	1177.94	646.12	1824.06
1990	1238.87	681.59	1920.46	1240.72	680.46	1921.18	1241.98	679.41	1921.39
1991	1306.09	716.70	2022.79	1308.27	715.47	2023.74	1309.50	714.42	2023.92
1992	1376.96	753.62	2130.58	1379.50	752.27	2131.77	1380.69	751.23	2131.92
1993	1451.67	792.44	2244.11	1454.61	790.97	2245.58	2455.75	789.94	2245.69
1994	1530.44	833.26	2363.70	1533.81	831.66	2365.47	1534.89	830.65	2365.54
1995	1613.48	876.18	2489.66	1617.32	874.44	2491.76	1618.33	873.45	2491.78
1996	1679.11	911.00	2590.11	1682.91	909.27	2592.18	1684.13	908.18	2592.31
1997	1747.41	947.21	2694.62	1751.16	945.50	2696.66	1752.61	944.28	2696.89
1998	1818.48	984.85	2803.34	1822.17	983.16	2805.33	1823.87	981.83	2805.70
1999	1892.45	1023.99	2916.44	1896.07	1022.33	2918.40	1898.02	1020.87	2918.88
2000	1969.42	1064.68	3034.11	1972.96	1063.05	3036.01	1975.20	1061.45	3036.65
2001	2049.53	1106.99	3156.53	2052.97	1105.40	3158.37	2055.51	1103.65	3159.16
2002	2132.89	1150.99	3283.89	2136.23	1149.44	3285.67	2139.08	1147.53	3286.61
2003	2219.65	1196.73	3416.38	2222.86	1195.23	3418.09	2226.06	1193.15	3419.21
2004	2309.93	1244.29	3554.23	2313.01	1242.84	3555.85	2316.57	1240.59	3557.16
2005	2403.89	1293.74	3697.63	2406.81	1292.35	3699.16	2410.76	1289.91	3700.67

Table 11-7 (Concluded)

50-25 nmi/10 min/2000 ft

Year	Fuel	Crew & Maint.	Total
1979	628.20	352.96	981.16
1980	675.99	378.76	1054.75
1981	727.41	406.44	1133.85
1982	782.74	436.15	1218.89
1983	842.28	568.03	1310.31
1984	906.35	502.24	1408.59
1985	955.64	528.15	1483.79
1986	1007.62	555.40	1563.02
1987	1062.42	584.06	1646.48
1988	1120.20	614.19	1734.39
1989	1181.12	645.88	1827.00
1990	1245.36	679.20	1924.56
1991	1313.09	714.24	2027.33
1992	1384.51	751.09	2135.60
1993	1459.80	789.85	2249.65
1994	1539.20	830.60	2369.80
1995	1622.91	873.45	2496.36
1996	1688.97	908.14	2597.11
1997	1757.73	944.20	2701.93
1998	1829.28	981.69	2810.97
1999	1903.74	1020.68	2924.42
2000	1981.24	1061.21	3042.45
2001	2061.89	1103.35	3165.24
2002	2145.82	1147.17	3292.99
2003	2233.17	1192.72	3425.89
2004	2324.07	1240.09	3564.16
2005	2418.68	1289.33	3708.10

11.8 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume VIII: Central East Pacific Region Flight Cost Model Results," Final Report No. FAA-EM-81-17, VIII (September 1981).

2. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume IX: Flight Cost Model Description," Final Report No. FAA-EM-81-17, IX (September 1981).

3. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume X: North Atlantic, Central East Pacific and Caribbean Regions Aviation Traffic Forecasts," Final Report No. FAA-EM-81-17, X (September 1981).

12.0 CEP PROVIDER FACILITIES COST

12.1 Introduction

The ATS unit and COM station facilities operated by the CEP providers involve O&M procedures similar to those in the NAT. The CEP facilities O&M costs are estimated in this section following the same process used to estimate the corresponding NAT costs.

12.2 ATS Unit Annual O&M Costs

Estimates of the CEP portion of the ATS annual O&M costs in 1979 for the FAAs Oakland and Honolulu ACCs have been presented (ref. 1). Allowing for an increase in these previous estimates due to certain overhead costs which were not originally included, the 1979 ATS facility O&M costs in the CEP are roughly projected to be $5 million. The O&M costs for present system continuance are assumed to increase at a 4.25% annually compounded growth rate based on a projected 195% CEP traffic increase from 1979 to 2005, as shown in Table 12-1.

The ATS facility capital improvement and O&M costs for any automatic dependent surveillance and cooperative independent surveillance potential improvements in the CEP are assumed to follow the same expenditure characteristics as those postulated for the NAT facilities, except that no additional RDT&E program costs are assumed to be required beyond those previously included in the NAT cost estimates in Section 7. The equipment costs are assumed to be $250 thousand per sector as estimated for the NAT, and the CEP provider capital cost estimates are calculated as follows. The two ATS units operated about 6 CEP sectors in 1979 with allowance for shared CEP and non-CEP responsibilities at each site. Assuming that automatic dependent surveillance operations could be initiated in 1990 and allowing for the 4.25% annual compound growth rate in sectorization, 9 sectors would be required in 1990 at a cost of $2.25 million as shown in Table 12-1. The 9 sector equipment units are assumed to be purchased in 1987 to allow time for installation and for a two-year operational shake-down in 1988 and 1989. Allowing for continued sectorization growth at the 4.25% rate, 3 additional sectors are assumed to be required every five years at a cost of $0.75 million in each of 1995, 2000 and 2005 as shown in Table 12-1.

Similar capital cost estimates are assumed for independent cooperative surveillance except that improvement operations are assumed to be initiated in 1995 with an initial purchase of 12 sector equipment units in 1992 at a cost of $3.0 million as shown in Table 12-1. (Note: These

Table 12-1

CEP ATS UNIT PROVIDER COST ESTIMATES
(Millions of 1979 US Dollars)

	Present System Continuance	Automatic Dependent Surveillance		Independent Cooperative Surveillance	
Year	Annual O&M*	Capital†	Annual O&M*	Capital†	Annual O&M*
1979	5.0				
1980	5.2				
1981	5.4				
1982	5.7				
1983	5.9				
1984	6.2				
1985	6.4				
1986	6.7				
1987	7.0	2.25	7.0		
1988	7.3		7.3		
1989	7.6		7.6		
1990	7.9		7.9		
1991	8.2		8.2		
1992	8.6		8.6	3.0	8.6
1993	9.0		9.0		9.0
1994	9.3		9.3		9.3
1995	9.7	0.75	9.7		9.7
1996	10.1		10.1		10.1
1997	10.6		10.6		10.6
1998	11.0		11.0		11.0
1999	11.5		11.5		11.5
2000	12.0	0.75	12.0	0.75	12.0
2001	12.5		12.5		12.5
2002	13.0		13.0		13.0
2003	13.6		13.6		13.6
2004	14.2		14.2		14.2
2005	14.8	0.75	14.8	0.75	14.8

*Indicated values are based on a 4.25% annual compound growth rate starting with the present system 1979 cost.

†Indicated values include a $2.25 million (or $3 million) initial equipment purchase cost and $0.75 million periodic equipment expansion costs; all capital costs assume a 20 year recovery life.

O&M cost estimates are provided for information purposes since the cooperative independent surveillance operation in the CEP is not explicitly addressed.)

In accordance with the discussions presented in Section 7, the ATS annual O&M costs for the automatic dependent and independent cooperative surveillance system are assumed to be the same as those for present system continuance as shown in Table 12-1.

12.3 COM Station Annual O&M Costs

Estimates of the 1979 COM station O&M costs for the CEP have been prepared (ref. 2) and show an annual cost of $1.2 million. The present system O&M costs are assumed to increase at the 4.25% annually compounded growth rate defined in the preceding paragraphs. Following the logic used to estimate NAT costs for the improvement alternatives, the annual O&M costs of the network HF system are assumed to be 42% of the corresponding present system continuance costs, and the annual O&M costs of the satellite and multiple satellite systems are assumed to be 33% of the corresponding present system continuance costs. The resulting annual costs shown in Table 12-2 represent the estimated expenses that would be required if the respective systems were in operation in the year indicated.

12.4 References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume III: Central East Pacific Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, III (September 1981).

2. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume V: North Atlantic, Central East Pacific and Caribbean Regions Communication Systems Descriptions," Final Report No. FAA-EM-81-17, V (September 1981).

Table 12-2

CEP COM FACILITY ANNUAL O&M COST ESTIMATES
(Millions of 1979 US Dollars)

Year	Present System Continuance*	Network HF Data Link & Voice†	Satellite Data Link and Voice or Multiple Satellite‡
1979	1.20		
1980	1.25		
1981	1.30		
1982	1.36		
1983	1.42		
1984	1.48		
1985	1.54		
1986	1.61		
1987	1.67		
1988	1.75		
1989	1.82		
1990	1.90	0.80	0.63
1991	1.98	0.83	0.65
1992	2.06	0.87	0.68
1993	2.15	0.90	0.71
1994	2.24	0.94	0.74
1995	2.34	0.98	0.77
1996	2.43	1.02	0.80
1997	2.54	1.07	0.84
1998	2.65	1.11	0.87
1999	2.76	1.16	0.91
2000	2.88	1.21	0.95
2001	3.00	1.26	0.99
2002	3.13	1.31	1.03
2003	3.26	1.37	1.08
2004	3.40	1.43	1.12
2005	3.54	1.49	1.17

*Indicated values are based on a 4.25% compound annual growth rate.

†Each indicated value is equal to 42% of the corresponding present system continuance cost.

‡Each indicated value is equal to 33% of the corresponding present system continuance cost.

13.0 CEP IMPROVEMENT CONFIGURATIONS AND COST COMPARISONS

13.1 Introduction

The CEP potential improvement configurations addressed in this section are extensions of some of the primary improvements considered for the NAT. Since the configuration components are similar to those described for the NAT (see Section 8), descriptions of the configuration constructions would be redundant and are not presented in this section. Instead, selected configurations are identified and their costs are compared.

13.2 Potential Improvement Configurations

The following set of improvement configurations is based on the assumption that each configuration is developed by evolutionary improvements to the 1979 present system and its continuance:

(1) Configuration 1. Baseline, HF SSB, 50 nmi/15 min/2000 ft through 1984, (50 nmi/10 min/2000 ft in 1985

(2) Configuration 2. 1000 ft Vertical Separation Oceanic Only, HF SSB Voice, 50 nmi/10 min/2000 ft in 1985

(3) Configuration 3. 1000 ft Vertical Separation Oceanic Only With Improved Altimetry, HF SSB Voice, 50 nmi/10 min/1000 ft in 1988

(4) Configuration 4. 1000 ft Vertical Separation Oceanic and Domestic, HF SSB Voice, 50 nmi/10 min/1000 ft in 1985

(5) Configuration 5. 1000 ft Vertical Separation Oceanic and Domestic With Improved Altimetry, HF SSB Voice, 50 nmi/10 min/1000 ft in 1988

(6) Configuration 6. Separation Assurance Device With 100% Avionics Capital Cost Allocation, HF SSB Voice, 25 nmi/5 min/2000 ft in 1990

(7) Configuration 7. Separation Assurance Device With 50% Avionics Capital Cost Allocation, HF SSB Voice, 25 nmi/5 min/2000 ft in 1990

(8) Configuration 8. Automatic Dependent Surveillance with Network HF Data Link and Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990

(9) Configuration 9. Automatic Dependent Surveillance with Satellite Data Link and Voice, MNPS (Improved), 25 nmi/5 min/2000 ft in 1990

The specific evolution of separation minima for each configuration is specified in Table 13-1. The separation minima corresponding to each improvement conform to the analogous separations defined for the NAT configurations. However, for the CEP, a 100 nmi rather than a 120 nmi initial lateral separation minimum is used, because of existing operating procedures, and a 25 nmi reduced lateral separation minimum is assumed for the CEP rather than the 30 nmi minimum assumed in the NAT. The baseline configuration assumes establishment of 50 nmi/10 min/ 2000 ft operations in 1985 based on analogous NAT procedural modifications to the separation minima although such modifications have not, as yet, been formally planned for the CEP.

The provider and user capital and O&M costs estimated for each configuration are shown in Tables 13-2 through 13-10. These data are based on the cost estmates given in Sections 10, 11, and 12 and assume that the respective improvements are coordinated with and dependent on similar improvements in the NAT, although, as previously mentioned, various CEP improvements could be implemented independently of NAT applications. The preliminary system design and development costs for the improvements are assumed to be required for NAT implementations and are not allocated to the CEP. The capital, O&M, and total costs estimated for each configuration during the 1979 through 2005 time period are summarized in Table 13-11.

13.3 Configuration Cost Comparisons

The 1979 present values of the user and provider capital, O&M, and total outlays during the 1979 through 2005 time period are shown in Tables 13-12 and Table 13-13 for each configuration. The present values are based on the same inflation and discount rate assumptions applied to the NAT.

Table 13-1

CEP POTENTIAL IMPROVEMENT CONFIGURATIONS

Configuration Components*	Separation Minimum Evolution	Support Requirements*
Configuration 1. Baseline	100-50 nmi/15 min/2000 ft, ORS & 100 nmi/15 min/2000 ft, elsewhere: 1979-1984	HF SSB
+ modification	50 nmi/10 min/2000 ft: 1985-2005	
Configuration 2. Baseline + 1000 Ft Vertical Oceanic Only	Baseline separation minima: 1979-1984 50 nmi/10 min/1000* ft: 1985-2005	HF SSB + PS (Vertical)
Configuration 3. Baseline + 1000 ft Vertical Oceanic Only With Improved Altimetry	Baseline separation minima: 1979-1987 50 nmi/10 min/1000* ft: 1988-2005	HF SSB + PS (Vertical)
Configuration 4. Baseline + 1000 ft Vertical Oceanic & Domestic	Baseline separation minima: 1979-1984 50 nmi/10 min/1000 ft: 1985-2005	HF SSB + PS (Vertical)
Configuration 5. Baseline + 1000 ft Vertical Oceanic & Domestic With Improved Altimetry	Baseline separation minima: 1979-1987 50 nmi/10 min/1000 ft: 1988-2005	HF SSB + PS (Vertical)
Configuration 6. Baseline + Separation Assurance Device With 100% Avionics Capital Cost Allocation	Baseline separation minima: 1979-1988 25 nmi/5 min/2000 ft: 1990-2005	HF SSB + MNPS (Improved)
Configuration 7. Baseline + Separation Assurance Device With 50% Avionics Capital Cost	Baseline separation minima: 1979-1988 25 nmi/5 min/2000 ft: 1990-2005	HF SSB + MNPS (Improved)
Configuration 8. Baseline + ADS With Network HF	Baseline separation minima: 1979-1989 25 nmi/5 min/2000 ft: 1990-2005	HF SSB + MNPS (Improved), Direct air-ground and Advanced ATC information processing
Configuration 9. Baseline + ADS With Satellite	Baseline separation minima: 1979-1989 25 nmi/5 min/2000 ft: 1990-2005	MNPS, HF SSB + MNPS (Improved), Direct air-ground and Advanced ATC information processing

*HF SSB = High-frequency single sideband pilot-radio operator air-ground voice communication
Direct air-ground = Direct pilot-controller data link or voice link or both.
Advanced ATC information processing = Automated ATC data handling, controller displays, and associated advanced ATC automation
MNPS = Minimum Navigation Performance Specification
PS = Performance Specification
ADS = Automatic Dependent Surveillance
CIS = Cooperative Independent Surveillance
Network HF = Network HF data link and voice
Simple Network HF = Simple Network HF data link and voice
Satellite = Satellite data link and voice
Multiple Satellite = Multiple satellite data link and voice
Separation Assurance Device = Airborne separation assurance device

TABLE 13-2
COST SUMMARY FOR CEP CONFIGURATION 1:
BASELINE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.000	0.000	0.000	956.73	528.13	1484.86	7.940	1484.860	1492.800	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.000	0.000	0.000	1008.76	555.36	1564.12	8.310	1564.120	1572.430	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.000	0.000	0.000	1063.61	583.99	1647.60	8.670	1647.600	1656.270	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.000	0.000	0.000	1121.45	614.10	1735.55	9.050	1735.550	1744.600	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.000	0.000	0.000	1182.43	645.75	1828.18	9.420	1828.180	1837.600	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.000	0.000	0.000	1246.73	679.04	1925.77	9.800	1925.770	1935.570	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.000	0.000	0.000	1314.52	714.05	2028.57	10.180	2028.570	2038.750	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.000	0.000	0.000	1386.00	750.86	2136.86	10.660	2136.860	2147.520	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.000	0.000	0.000	1461.37	789.57	2250.94	11.150	2250.940	2262.090	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.000	0.000	0.000	1540.83	830.28	2371.11	11.540	2371.110	2382.650	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.000	0.000	0.000	1624.62	873.08	2497.70	12.040	2497.700	2509.740	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.000	0.000	0.000	1690.80	907.82	2598.62	12.530	2598.620	2611.150	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.000	0.000	0.000	1759.68	943.94	2703.62	13.140	2703.620	2716.760	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.000	0.000	0.000	1831.37	981.49	2812.86	13.650	2812.860	2826.510	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.000	0.000	0.000	1905.98	1020.54	2926.52	14.260	2926.520	2940.780	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.000	0.000	0.000	1983.62	1061.15	3044.77	14.880	3044.770	3059.650	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.000	0.000	0.000	2064.43	1103.37	3167.80	15.500	3167.800	3183.300	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.000	0.000	0.000	2148.53	1147.27	3295.80	16.430	3295.800	3311.930	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.000	0.000	0.000	2236.06	1192.92	3428.98	16.860	3428.980	3445.840	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.000	0.000	0.000	2327.16	1240.38	3567.54	17.600	3567.540	3585.140	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.000	0.000	0.000	2421.96	1289.73	3711.69	18.340	3711.690	3730.030	2005

TABLE 13-3

COST SUMMARY FOR CEP CONFIGURATION 2:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.000	0.000	0.000	951.82	529.52	1481.34	7.940	1481.340	1489.280	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.000	0.000	0.000	1003.64	556.76	1560.40	8.310	1560.400	1568.710	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.000	0.000	0.000	1058.28	585.40	1643.68	8.670	1643.680	1652.350	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.000	0.000	0.000	1115.90	615.51	1731.41	9.050	1731.410	1740.460	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.000	0.000	0.000	1176.66	647.17	1823.83	9.420	1823.830	1833.250	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.000	0.000	0.000	1240.72	680.46	1921.18	9.800	1921.180	1930.980	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.000	0.000	0.000	1308.27	715.47	2023.74	10.180	2023.740	2033.920	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.000	0.000	0.000	1379.50	752.27	2131.77	10.660	2131.770	2142.430	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.000	0.000	0.000	1454.61	790.97	2245.58	11.150	2245.580	2256.730	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.000	0.000	0.000	1533.81	831.66	2365.47	11.540	2365.470	2377.010	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.000	0.000	0.000	1617.32	874.44	2491.76	12.040	2491.760	2503.800	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.000	0.000	0.000	1682.91	909.27	2592.18	12.530	2592.180	2604.710	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.000	0.000	0.000	1751.16	945.50	2696.66	13.140	2696.660	2709.800	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.000	0.000	0.000	1822.17	983.16	2805.33	13.650	2805.330	2818.980	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.000	0.000	0.000	1896.07	1022.33	2918.40	14.260	2918.400	2932.660	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.000	0.000	0.000	1972.96	1063.05	3036.01	14.880	3036.010	3050.890	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.000	0.000	0.000	2052.97	1105.40	3158.37	15.500	3158.370	3173.870	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.000	0.000	0.000	2136.23	1149.44	3285.67	16.130	3285.670	3301.800	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.000	0.000	0.000	2222.86	1195.23	3418.09	16.860	3418.090	3434.950	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.000	0.000	0.000	2313.01	1242.84	3555.85	17.600	3555.850	3573.450	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.000	0.000	0.000	2406.81	1292.35	3699.16	18.340	3699.160	3717.500	2005

TABLE 13-4
COST SUMMARY FOR CEP CONFIGURATION 3:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.335	0.002	0.337	956.73	528.13	1484.86	7.940	1485.197	1493.137	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.335	0.002	0.337	1008.76	555.36	1564.12	8.310	1564.457	1572.767	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.335	0.002	0.337	1063.61	583.99	1647.60	8.670	1647.937	1656.607	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.015	0.002	0.017	1115.90	615.51	1731.41	9.050	1731.427	1740.477	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.015	0.002	0.017	1176.66	647.17	1823.83	9.420	1823.847	1833.267	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.015	0.003	0.018	1240.72	680.46	1921.18	9.800	1921.198	1930.998	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.015	0.003	0.018	1308.27	715.47	2023.74	10.180	2023.758	2033.938	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.015	0.003	0.018	1379.50	752.27	2131.77	10.660	2131.788	2142.448	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.015	0.003	0.018	1454.61	790.97	2245.58	11.150	2245.598	2256.748	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.015	0.003	0.018	1533.81	831.66	2365.47	11.540	2365.488	2377.028	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.015	0.003	0.018	1617.32	874.44	2491.76	12.040	2491.778	2503.818	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.015	0.003	0.018	1682.91	909.27	2592.18	12.530	2592.198	2604.728	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.015	0.004	0.019	1751.16	945.50	2696.66	13.140	2696.679	2709.819	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.015	0.004	0.019	1822.17	983.16	2805.33	13.650	2805.349	2818.999	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.015	0.004	0.019	1896.07	1022.33	2918.40	14.260	2918.419	2932.679	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.015	0.004	0.019	1972.96	1063.05	3036.01	14.880	3036.029	3050.909	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.015	0.004	0.019	2052.97	1105.40	3158.37	15.500	3158.389	3173.889	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.015	0.004	0.019	2136.23	1149.44	3285.67	16.130	3285.689	3301.819	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.015	0.004	0.019	2222.86	1195.23	3418.09	16.860	3418.109	3434.969	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.015	0.005	0.020	2313.01	1242.84	3555.85	17.600	3555.870	3573.470	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.015	0.005	0.020	2406.81	1292.35	3699.16	18.340	3699.180	3717.520	2005

TABLE 13-5

COST SUMMARY FOR CEP CONFIGURATION 4:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.000	0.000	0.000	951.24	530.22	1481.46	7.940	1481.460	1489.400	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.000	0.000	0.000	1002.85	557.54	1560.39	8.310	1560.390	1568.700	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.000	0.000	0.000	1057.26	586.25	1643.51	8.670	1643.510	1652.180	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.000	0.000	0.000	1114.63	616.45	1731.08	9.050	1731.080	1740.130	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.000	0.000	0.000	1175.11	648.21	1823.32	9.420	1823.320	1832.740	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.000	0.000	0.000	1238.87	681.59	1920.46	9.800	1920.460	1930.260	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.000	0.000	0.000	1306.09	716.70	2022.79	10.180	2022.790	2032.970	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.000	0.000	0.000	1376.96	753.62	2130.58	10.660	2130.580	2141.240	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.000	0.000	0.000	1451.67	792.44	2244.11	11.150	2244.110	2255.260	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.000	0.000	0.000	1530.44	833.26	2363.70	11.540	2363.700	2375.240	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.000	0.000	0.000	1613.48	876.18	2489.66	12.040	2489.660	2501.700	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.000	0.000	0.000	1679.11	911.00	2590.11	12.530	2590.110	2602.640	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.000	0.000	0.000	1747.41	947.21	2694.62	13.140	2694.620	2707.760	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.000	0.000	0.000	1818.48	984.85	2803.33	13.650	2803.330	2816.980	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.000	0.000	0.000	1892.45	1023.99	2916.44	14.260	2916.440	2930.700	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.000	0.000	0.000	1969.42	1064.68	3034.10	14.880	3034.100	3048.980	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.000	0.000	0.000	2049.53	1106.99	3156.52	15.500	3156.520	3172.020	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.000	0.000	0.000	2132.89	1150.99	3283.88	16.130	3283.880	3300.010	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.000	0.000	0.000	2219.65	1196.73	3416.38	16.860	3416.380	3433.240	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.000	0.000	0.000	2309.93	1244.29	3554.22	17.600	3554.220	3571.820	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.000	0.000	0.000	2403.89	1293.74	3697.63	18.340	3697.630	3715.970	2005

TABLE 13-6
COST SUMMARY FOR CEP CONFIGURATION 5:
1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
WITH IMPROVED ALTIMETRY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.335	0.002	0.337	956.73	528.13	1484.86	7.940	1485.197	1493.137	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.335	0.002	0.337	1008.76	555.36	1564.12	8.310	1564.457	1572.767	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.335	0.002	0.337	1063.61	583.99	1647.60	8.670	1647.937	1656.607	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.015	0.002	0.017	1114.63	616.45	1731.08	9.050	1731.097	1740.146	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.015	0.002	0.017	1175.11	648.21	1823.32	9.420	1823.337	1832.757	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.015	0.003	0.018	1238.87	681.59	1920.46	9.800	1920.478	1930.278	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.015	0.003	0.018	1306.09	716.70	2022.79	10.180	2022.808	2032.988	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.015	0.003	0.018	1376.96	753.62	2130.58	10.660	2130.598	2141.258	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.015	0.003	0.018	1451.67	792.44	2244.11	11.150	2244.128	2255.278	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.015	0.003	0.018	1530.44	833.26	2363.70	11.540	2363.718	2375.258	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.015	0.003	0.018	1613.48	876.18	2489.66	12.040	2489.678	2501.718	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.015	0.003	0.018	1679.11	911.00	2590.11	12.530	2590.128	2602.658	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.015	0.004	0.019	1747.41	947.21	2694.62	13.140	2694.639	2707.779	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.015	0.004	0.019	1818.48	984.85	2803.33	13.650	2803.349	2816.999	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.015	0.004	0.019	1892.45	1023.99	2916.44	14.260	2916.459	2930.719	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.015	0.004	0.019	1969.42	1064.68	3034.10	14.880	3034.119	3048.999	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.015	0.004	0.019	2049.53	1106.99	3156.52	15.500	3156.539	3172.039	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.015	0.004	0.019	2132.89	1150.99	3283.88	16.130	3283.899	3300.029	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.015	0.004	0.019	2219.65	1196.73	3416.38	16.860	3416.399	3433.259	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.015	0.005	0.020	2309.93	1244.29	3554.22	17.600	3554.240	3571.840	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.015	0.005	0.020	2403.89	1293.74	3697.63	18.340	3697.650	3715.990	2005

TABLE 13-7

COST SUMMARY FOR CEP CONFIGURATION 6:
SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	1.798	0.145	1.943	956.73	528.13	1484.86	7.940	1486.803	1494.743	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	1.798	0.148	1.946	1008.76	555.36	1564.12	8.310	1566.066	1574.376	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	1.798	0.151	1.949	1063.61	583.99	1647.60	8.670	1649.549	1658.219	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.146	0.155	0.301	1121.45	614.10	1735.55	9.050	1735.851	1744.901	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.146	0.159	0.305	1182.43	645.75	1828.18	9.420	1828.485	1837.905	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.146	0.162	0.308	1243.64	679.43	1923.07	9.800	1923.378	1933.177	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.146	0.166	0.312	1311.21	714.44	2025.65	10.180	2025.962	2036.142	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.146	0.170	0.316	1382.45	751.25	2133.70	10.660	2134.016	2144.676	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.146	0.174	0.320	1457.56	789.95	2247.51	11.150	2247.830	2258.980	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.146	0.178	0.324	1536.75	830.65	2367.40	11.540	2367.724	2379.264	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.146	0.182	0.328	1620.24	873.45	2493.69	12.040	2494.018	2506.058	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.146	0.187	0.333	1686.19	908.19	2594.38	12.530	2594.713	2607.242	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.146	0.191	0.337	1754.83	944.31	2699.14	13.140	2699.477	2712.617	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.146	0.195	0.341	1826.26	981.87	2808.13	13.650	2808.471	2822.121	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.146	0.199	0.345	1900.60	1020.92	2921.52	14.260	2921.865	2936.125	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.146	0.204	0.350	1977.96	1061.52	3039.48	14.880	3039.830	3054.710	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.146	0.208	0.354	2058.47	1103.74	3162.21	15.500	3162.564	3178.064	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.146	0.212	0.358	2142.26	1147.64	3289.90	16.130	3290.258	3306.388	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.146	0.216	0.362	2229.47	1193.28	3422.75	16.860	3423.112	3439.972	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.146	0.220	0.366	2320.22	1240.74	3560.96	17.600	3561.326	3578.926	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.146	0.224	0.370	2414.66	1290.09	3704.75	18.340	3705.120	3723.460	2005

TABLE 13-8
COST SUMMARY FOR CEP CONFIGURATION 7:
SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.000	0.000	0.000	1.54	6.40	7.94	0.899	0.145	1.044	956.73	528.13	1484.86	7.940	1485.904	1493.844	1985
1986	0.000	0.000	0.000	1.61	6.70	8.31	0.899	0.148	1.047	1008.76	555.36	1564.12	8.310	1565.167	1573.477	1986
1987	0.000	0.000	0.000	1.67	7.00	8.67	0.899	0.151	1.050	1063.61	583.99	1647.60	8.670	1648.650	1657.320	1987
1988	0.000	0.000	0.000	1.75	7.30	9.05	0.073	0.155	0.228	1121.45	614.10	1735.55	9.050	1735.778	1744.828	1988
1989	0.000	0.000	0.000	1.82	7.60	9.42	0.073	0.159	0.232	1182.43	645.75	1828.18	9.420	1828.412	1837.832	1989
1990	0.000	0.000	0.000	1.90	7.90	9.80	0.073	0.162	0.235	1243.64	679.43	1923.07	9.800	1923.305	1933.104	1990
1991	0.000	0.000	0.000	1.98	8.20	10.18	0.073	0.166	0.239	1311.21	714.44	2025.65	10.180	2025.889	2036.069	1991
1992	0.000	0.000	0.000	2.06	8.60	10.66	0.073	0.170	0.243	1382.45	751.25	2133.70	10.660	2133.943	2144.603	1992
1993	0.000	0.000	0.000	2.15	9.00	11.15	0.073	0.174	0.247	1457.56	789.95	2247.51	11.150	2247.757	2258.907	1993
1994	0.000	0.000	0.000	2.24	9.30	11.54	0.073	0.178	0.251	1536.75	830.65	2367.40	11.540	2367.651	2379.191	1994
1995	0.000	0.000	0.000	2.34	9.70	12.04	0.073	0.182	0.255	1620.24	873.45	2493.69	12.040	2493.945	2505.985	1995
1996	0.000	0.000	0.000	2.43	10.10	12.53	0.073	0.187	0.260	1686.19	908.19	2594.38	12.530	2594.640	2607.169	1996
1997	0.000	0.000	0.000	2.54	10.60	13.14	0.073	0.191	0.264	1754.83	944.31	2699.14	13.140	2699.404	2712.544	1997
1998	0.000	0.000	0.000	2.65	11.00	13.65	0.073	0.195	0.268	1826.26	981.87	2808.13	13.650	2808.398	2822.048	1998
1999	0.000	0.000	0.000	2.76	11.50	14.26	0.073	0.199	0.272	1900.60	1020.92	2921.52	14.260	2921.792	2936.052	1999
2000	0.000	0.000	0.000	2.88	12.00	14.88	0.073	0.204	0.277	1977.96	1061.52	3039.48	14.880	3039.757	3054.637	2000
2001	0.000	0.000	0.000	3.00	12.50	15.50	0.073	0.208	0.281	2058.47	1103.74	3162.21	15.500	3162.491	3177.991	2001
2002	0.000	0.000	0.000	3.13	13.00	16.13	0.073	0.212	0.285	2142.26	1147.64	3289.90	16.130	3290.185	3306.315	2002
2003	0.000	0.000	0.000	3.26	13.60	16.86	0.073	0.216	0.289	2229.47	1193.28	3422.75	16.860	3423.039	3439.899	2003
2004	0.000	0.000	0.000	3.40	14.20	17.60	0.073	0.220	0.293	2320.22	1240.74	3560.96	17.600	3561.253	3578.853	2004
2005	0.000	0.000	0.000	3.54	14.80	18.34	0.073	0.224	0.297	2414.66	1290.09	3704.75	18.340	3705.047	3723.387	2005

TABLE 13-9

COST SUMMARY FOR CEP CONFIGURATION 8:
AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.500	0.000	0.500	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.820	1312.490	1320.310	1983
1984	0.471	0.100	0.571	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	8.251	1411.270	1419.521	1984
1985	0.471	0.100	0.571	1.54	6.40	7.94	1.505	0.145	1.650	956.73	528.13	1484.86	8.511	1486.510	1495.021	1985
1986	0.471	0.100	0.571	1.61	6.70	8.31	1.505	0.148	1.653	1008.76	555.36	1564.12	8.881	1565.773	1574.654	1986
1987	0.471	0.220	0.691	1.67	7.00	8.67	1.505	0.151	1.656	1063.61	583.99	1647.60	9.361	1649.256	1658.617	1987
1988	0.000	0.220	0.220	1.75	7.30	9.05	0.129	0.155	0.284	1121.45	614.10	1735.55	9.270	1735.834	1745.104	1988
1989	0.000	0.220	0.220	1.82	7.60	9.42	0.129	0.159	0.288	1182.43	645.75	1828.18	9.640	1828.468	1838.108	1989
1990	0.000	0.220	0.220	0.80	7.90	8.70	0.129	0.162	0.291	1243.64	679.43	1923.07	8.920	1923.361	1932.281	1990
1991	0.000	0.220	0.220	0.83	8.20	9.03	0.129	0.166	0.295	1311.21	714.44	2025.65	9.250	2025.945	2035.195	1991
1992	0.000	0.220	0.220	0.87	8.60	9.47	0.129	0.170	0.299	1382.45	751.25	2133.70	9.690	2133.999	2143.689	1992
1993	0.000	0.220	0.220	0.90	9.00	9.90	0.129	0.174	0.303	1457.56	789.95	2247.51	10.120	2247.813	2257.933	1993
1994	0.000	0.220	0.220	0.94	9.30	10.24	0.129	0.178	0.307	1536.75	830.65	2367.40	10.460	2367.707	2378.167	1994
1995	0.000	0.220	0.220	0.98	9.70	10.68	0.129	0.182	0.311	1620.24	873.45	2493.69	10.900	2494.001	2504.901	1995
1996	0.000	0.220	0.220	1.02	10.10	11.12	0.129	0.187	0.316	1686.19	908.19	2594.38	11.340	2594.696	2606.036	1996
1997	0.000	0.220	0.220	1.07	10.60	11.67	0.129	0.191	0.320	1754.83	944.31	2699.14	11.890	2699.460	2711.350	1997
1998	0.000	0.220	0.220	1.11	11.00	12.11	0.129	0.195	0.324	1826.26	981.87	2808.13	12.330	2808.454	2820.784	1998
1999	0.000	0.220	0.220	1.16	11.50	12.66	0.129	0.199	0.328	1900.60	1020.92	2921.52	12.880	2921.848	2934.728	1999
2000	0.000	0.220	0.220	1.21	12.00	13.21	0.129	0.204	0.333	1977.96	1061.52	3039.48	13.430	3039.813	3053.243	2000
2001	0.000	0.220	0.220	1.26	12.50	13.76	0.129	0.208	0.337	2058.47	1103.74	3162.21	13.980	3162.547	3176.527	2001
2002	0.000	0.220	0.220	1.31	13.00	14.31	0.129	0.212	0.341	2142.26	1147.64	3289.90	14.530	3290.241	3304.771	2002
2003	0.000	0.220	0.220	1.37	13.60	14.97	0.129	0.216	0.345	2229.47	1193.28	3422.75	15.190	3423.095	3438.285	2003
2004	0.000	0.220	0.220	1.43	14.20	15.63	0.129	0.220	0.349	2320.22	1240.74	3560.96	15.850	3561.309	3577.159	2004
2005	0.000	0.220	0.220	1.49	14.80	16.29	0.129	0.224	0.353	2414.66	1290.09	3704.75	16.510	3705.103	3721.613	2005

TABLE 13-10

COST SUMMARY FOR CEP CONFIGURATION 9:

AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	1.20	5.00	6.20	0.000	0.000	0.000	628.90	352.96	981.86	6.200	981.860	988.060	1979
1980	0.000	0.000	0.000	1.25	5.20	6.45	0.000	0.000	0.000	676.99	378.76	1055.75	6.450	1055.750	1062.200	1980
1981	0.000	0.000	0.000	1.30	5.40	6.70	0.000	0.000	0.000	728.75	406.44	1135.19	6.700	1135.190	1141.890	1981
1982	0.000	0.000	0.000	1.36	5.70	7.06	0.000	0.000	0.000	784.48	436.15	1220.63	7.060	1220.630	1227.690	1982
1983	0.000	0.000	0.000	1.42	5.90	7.32	0.000	0.000	0.000	844.46	468.03	1312.49	7.320	1312.490	1319.810	1983
1984	0.000	0.000	0.000	1.48	6.20	7.68	0.000	0.000	0.000	909.03	502.24	1411.27	7.680	1411.270	1418.950	1984
1985	0.326	0.000	0.326	1.54	6.40	7.94	1.792	0.145	1.937	956.73	528.13	1484.86	8.266	1486.797	1495.063	1985
1986	9.026	0.300	9.326	1.61	6.70	8.31	1.792	0.148	1.940	1008.76	555.36	1564.12	17.636	1566.060	1583.696	1986
1987	0.326	0.325	0.651	1.67	7.00	8.67	1.792	0.151	1.943	1063.61	583.99	1647.60	9.321	1649.543	1658.864	1987
1988	6.026	0.350	6.376	1.75	7.30	9.05	0.150	0.155	0.305	1121.45	614.10	1735.55	15.426	1735.855	1751.281	1988
1989	0.000	0.350	0.350	1.82	7.60	9.42	0.150	0.159	0.309	1182.43	645.75	1828.18	9.770	1828.489	1838.259	1989
1990	0.000	0.350	0.350	0.63	7.90	8.53	0.150	0.162	0.312	1243.64	679.43	1923.07	8.880	1923.382	1932.261	1990
1991	0.000	0.350	0.350	0.65	8.20	8.85	0.150	0.166	0.316	1311.21	714.44	2025.65	9.200	2025.966	2035.166	1991
1992	0.000	0.350	0.350	0.68	8.60	9.28	0.150	0.170	0.320	1382.45	751.25	2133.70	9.630	2134.020	2143.650	1992
1993	5.700	0.350	6.050	0.71	9.00	9.71	0.150	0.174	0.324	1457.56	789.95	2247.51	15.760	2247.834	2263.594	1993
1994	0.000	0.350	0.350	0.74	9.30	10.04	0.150	0.178	0.328	1536.75	830.65	2367.40	10.390	2367.728	2378.118	1994
1995	5.700	0.350	6.050	0.77	9.70	10.47	0.150	0.182	0.332	1620.24	873.45	2493.69	16.520	2494.022	2510.542	1995
1996	0.000	0.350	0.350	0.80	10.10	10.90	0.150	0.187	0.337	1686.19	908.19	2594.38	11.250	2594.717	2605.967	1996
1997	0.000	0.350	0.350	0.84	10.60	11.44	0.150	0.191	0.341	1754.83	944.31	2699.14	11.790	2699.481	2711.271	1997
1998	0.000	0.350	0.350	0.87	11.00	11.87	0.150	0.195	0.345	1826.26	981.87	2808.13	12.220	2808.475	2820.695	1998
1999	0.000	0.350	0.350	0.91	11.50	12.41	0.150	0.199	0.349	1900.60	1020.92	2921.52	12.760	2921.869	2934.629	1999
2000	5.700	0.350	6.050	0.95	12.00	12.95	0.150	0.204	0.354	1977.96	1061.52	3039.48	19.000	3039.834	3058.833	2000
2001	0.000	0.350	0.350	0.99	12.50	13.49	0.150	0.208	0.358	2058.47	1103.74	3162.21	13.840	3162.568	3176.408	2001
2002	5.700	0.350	6.050	1.03	13.00	14.03	0.150	0.212	0.362	2141.26	1147.64	3288.90	20.080	3289.262	3309.342	2002
2003	0.000	0.350	0.350	1.08	13.60	14.68	0.150	0.216	0.366	2229.47	1193.28	3422.75	15.030	3423.116	3438.146	2003
2004	0.000	0.350	0.350	1.12	14.20	15.32	0.150	0.220	0.370	2320.22	1240.74	3560.96	15.670	3561.330	3577.000	2004
2005	0.000	0.350	0.350	1.17	14.80	15.97	0.150	0.224	0.374	2414.66	1290.09	3704.75	16.320	3705.124	3721.444	2005

TABLE 13-11

COST SUMMARY TOTALS OVER ALL YEARS FOR ALL CEP CONFIGURATIONS

(1979 US $ MILLIONS)

CONFIGURATION	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			CONFIGURATION
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1	0.000	0.000	0.000	58.66	244.40	303.06	0.000	0.000	0.000	38849.200	20997.360	59846.600	303.059	59846.600	60149.660	1
2	0.000	0.000	0.000	58.66	244.40	303.06	0.000	0.000	0.000	38670.240	21032.740	59703.030	303.059	59703.030	60006.070	2
3	0.000	0.000	0.000	58.66	244.40	303.06	1.275	0.069	1.344	38685.600	21028.540	59714.190	303.059	59715.530	60018.590	3
4	0.000	0.000	0.000	58.66	244.40	303.06	0.000	0.000	0.000	38613.920	21061.480	59675.430	303.059	59675.430	59978.490	4
5	0.000	0.000	0.000	58.66	244.40	303.06	1.275	0.069	1.344	38631.670	21054.940	59686.660	303.059	59688.000	59991.050	5
6	0.000	0.000	0.000	58.66	244.40	303.06	8.022	3.846	11.868	38768.320	21003.350	59771.690	303.059	59783.560	60086.610	6
7	0.000	0.000	0.000	58.66	244.40	303.06	4.011	3.846	7.857	38768.320	21003.350	59771.690	303.059	59779.540	60082.610	7
8	2.384	4.480	6.864	34.15	244.40	278.55	6.837	3.846	10.683	38768.320	21003.350	59771.690	285.414	59782.380	60067.770	8
9	38.504	6.925	45.429	30.34	244.40	274.74	8.076	3.846	11.922	38767.320	21003.350	59770.690	320.168	59782.620	60102.780	9

ALTERNATIVE NUMBER	ALTERNATIVE NAME
1	BASELINE
2	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
3	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
5	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC WITH IMPROVED ALTIMETRY
6	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
7	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
8	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
9	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 13-12

PRESENT VALUE COST SUMMARY TOTALS OVER ALL YEARS FOR ALL CEP CONFIGURATIONS

(1979 DISCOUNTED US $ MILLIONS)

CONFIG URATION	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			CONFIG URATION
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1	0.	0.	0.	45.	186.	230.	0.	0.	0.	29437.	12273.	41710.	230.	41710.	41941.	1
2	0.	0.	0.	45.	186.	230.	0.	0.	0.	29307.	12292.	41600.	230.	41600.	41830.	2
3	0.	0.	0.	45.	186.	230.	1.	0.	1.	29321.	12289.	41610.	230.	41611.	41841.	3
4	0.	0.	0.	45.	186.	230.	0.	0.	0.	29266.	12308.	41575.	230.	41575.	41805.	4
5	0.	0.	0.	45.	186.	230.	1.	0.	1.	29282.	12303.	41585.	230.	41586.	41816.	5
6	0.	0.	0.	45.	186.	230.	5.	2.	7.	29380.	12276.	41656.	230.	41664.	41894.	6
7	0.	0.	0.	45.	186.	230.	2.	2.	5.	29380.	12276.	41656.	230.	41661.	41891.	7
8	2.	3.	5.	27.	186.	213.	4.	2.	6.	29380.	12276.	41656.	219.	41663.	41881.	8
9	28.	5.	33.	25.	186.	210.	5.	2.	7.	29380.	12276.	41656.	243.	41663.	41906.	9

ALTER-NATIVE NUMBER	ALTER-NATIVE NAME
1	BASELINE
2	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
3	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
5	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC WITH IMPROVED ALTIMETRY
6	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
7	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
8	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
9	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 13-13
PRESENT VALUE 1979-2005 CEP CONFIGURATIONS COSTS
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	41710.	41710.	0.	230.	230.	0.	41941.	41941.	BASELINE
2	0.	41600.	41600.	0.	230.	230.	0.	41830.	41830.	1000 FT OCEANIC
3	1.	41610.	41611.	0.	230.	230.	1.	41840.	41841.	1000 FT OCEANIC + ALTIMETRY
4	0.	41575.	41575.	0.	230.	230.	0.	41805.	41805.	1000 FT EVERYWHERE
5	1.	41585.	41586.	0.	230.	230.	1.	41816.	41816.	1000 FT EVERYWHERE + ALTIMETRY
6	5.	41659.	41664.	0.	230.	230.	5.	41889.	41894.	SEP AS DEV, 100% AVIONICS COST
7	2.	41659.	41661.	0.	230.	230.	2.	41889.	41891.	SEP AS DEV, 50% AVIONICS COST
8	4.	41659.	41663.	2.	216.	219.	6.	41875.	41881.	ADS WITH NETWORK HF
9	5.	41658.	41663.	28.	216.	243.	33.	41873.	41906.	ADS WITH SAT

The 1979 present values of the net savings relative to the baseline configuration are presented in Tables 13-14 and 13-15 for each configuration. The net savings results are the same as those obtained for the NAT in terms of the economic feasibilities of the various configurations. The discussions in Section 9 addressing NAT configuration cost comparisons apply, in general, to the CEP configuration costs.

TABLE 13-14

PRESENT VALUE NET SAVINGS TOTALS OVER ALL YEARS FOR EACH CEP CONFIGURATION

(1979 DISCOUNTED US $ MILLIONS)

CONFIG URATION	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			CONFIG URATION
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	130.	-19.	110.	0.	110.	110.	2
3	0.	0.	0.	0.	0.	0.	-1.	-0.	-1.	116.	-16.	100.	0.	99.	99.	3
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	171.	-35.	136.	0.	136.	136.	4
5	0.	0.	0.	0.	0.	0.	-1.	-0.	-1.	155.	-30.	125.	0.	124.	124.	5
6	0.	0.	0.	0.	0.	0.	-5.	-2.	-7.	57.	-3.	54.	0.	47.	47.	6
7	0.	0.	0.	0.	0.	0.	-2.	-2.	-5.	57.	-3.	54.	0.	49.	49.	7
8	-2.	-3.	-5.	17.	0.	17.	-4.	-2.	-6.	57.	-3.	54.	12.	48.	59.	8
9	-28.	-5.	-33.	20.	0.	20.	-5.	-2.	-7.	58.	-3.	55.	-13.	47.	34.	9

CONFIG-URATION NUMBER	CONFIG-URATION NAME
1	BASELINE
2	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY
3	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC ONLY WITH IMPROVED ALTIMETRY
4	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC
5	1000 FT VERTICAL SEPARATION ABOVE FL 290 OCEANIC AND DOMESTIC WITH IMPROVED ALTIMETRY
6	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
7	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
8	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
9	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 13-15

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH CEP CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
2	0.	110.	110.	0.	0.	0.	0.	110.	110.	1000 FT OCEANIC
3	-1.	100.	99.	0.	0.	0.	-1.	100.	99.	1000 FT OCEANIC + ALTIMETRY
4	0.	136.	136.	0.	0.	0.	0.	136.	136.	1000 FT EVERYWHERE
5	-1.	125.	124.	0.	0.	0.	-1.	125.	124.	1000 FT EVERYWHERE + ALTIMETRY
6	-5.	52.	47.	0.	0.	0.	-5.	52.	47.	SEP AS DEV, 100% AVIONICS COST
7	-2.	52.	49.	0.	0.	0.	-2.	52.	49.	SEP AS DEV, 50% AVIONICS COST
8	-4.	52.	48.	-2.	14.	12.	-6.	66.	59.	ADS WITH NETWORK HF
9	-5.	52.	47.	-28.	15.	-13.	-33.	67.	34.	ADS WITH SAT

14. CAR Potential Improvments and Costs

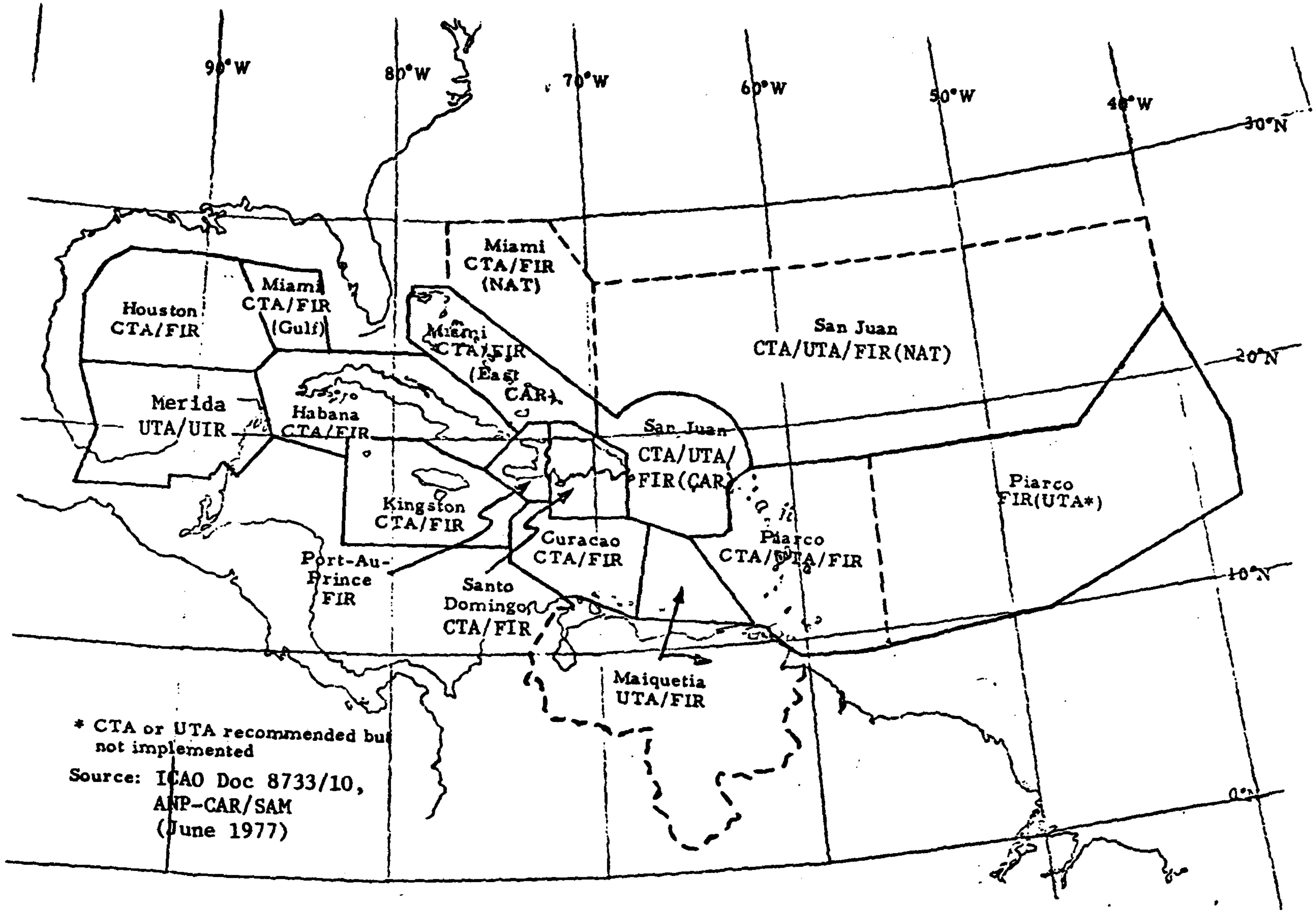
14.1 Introduction

The HF data link, satellite and separation assurance device options considered for the NAT might be applied to the CAR. This section estimates the costs of such extensions based on the assumption that developmental and other costs are borne by associated NAT improvements.

The CAR, for the purposes of this report, as shown in Figure 14-1, includes the Curacao, Habana, Houston, Kingston, Maiquetia, Merida, Piarco and Santo Domingo CTA/FIRs, parts of the Miami and San Juan CTA/FIRs, and the Port-au-Prince FIR. The CAR differs substantially from the NAT and CEP. For example, the CAR includes terminal as well as enroute ATC facilities. It has radar coverage in selected areas (see Figure 14-2), and VHF communications in some terminal areas and along some major routes (e.g., the San Juan-Miami corridor). Unlike other areas considered, the CAR has an extensive network of routes served by ground based navigation aids including a large number of NDBs.

The land masses in the CAR could provide more high altitude VHF coverage from ground-based air-ground communication transceiver sites than presently available. Figure 14-3 shows the (approximate) limits of coverage that might be obtained with conventional land based VHF transceivers without respect to terrain, economic, institutional or other factors. In practice, almost complete air-ground communication coverage of the Gulf of Mexico might be obtained using extended range VHF. Certain carriers are already certificated to fly some Gulf of Mexico routes (subject to minimum altitude restriction) using privately operated remote VHF transceivers. The uncontrolled eastern deep ocean portion of the Piarco FIR is the only region which is totally dependent on HF coverage. (Note that a large part of the San Juan CTA/FIR is assumed to be in the NAT for analysis purposes; see Figure 14-1.)

Enroute high altitude traffic flow in the CAR is discussed in reference 1. The uncontrolled eastern area of Piarco is estimated, on peak days, to have a total of 16 aircraft flying through it. The peak instantaneous aircraft count, based on this traffic flow might only be one or two aircraft. Reference 1 indicates an instantaneous peaking of 49 scheduled aircraft in the entire CAR. However, many of these aircraft are estimated to be in parts of the CAR airspace which are served by VHF communications. Only 10 to 20 aircraft may actually require HF SSB air-ground communications at any one time.



* CTA or UTA recommended but not implemented

Source: ICAO Doc 8733/10, ANP-CAR/SAM (June 1977)

FIGURE 14-1 CAR AIRSPACE JURISDICTIONAL STRUCTURE

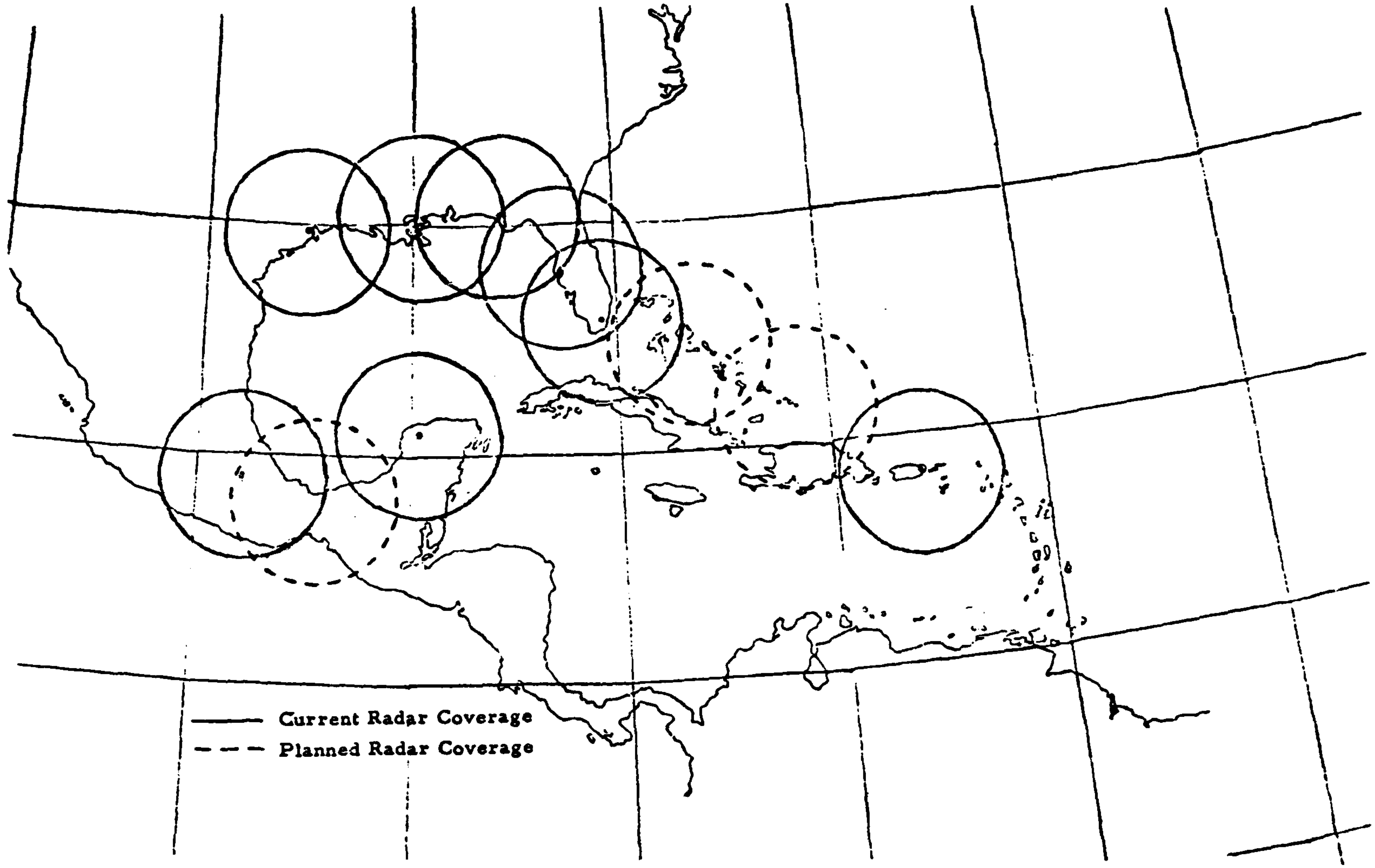


FIGURE 14-2 CAR EN ROUTE RADAR COVERAGE

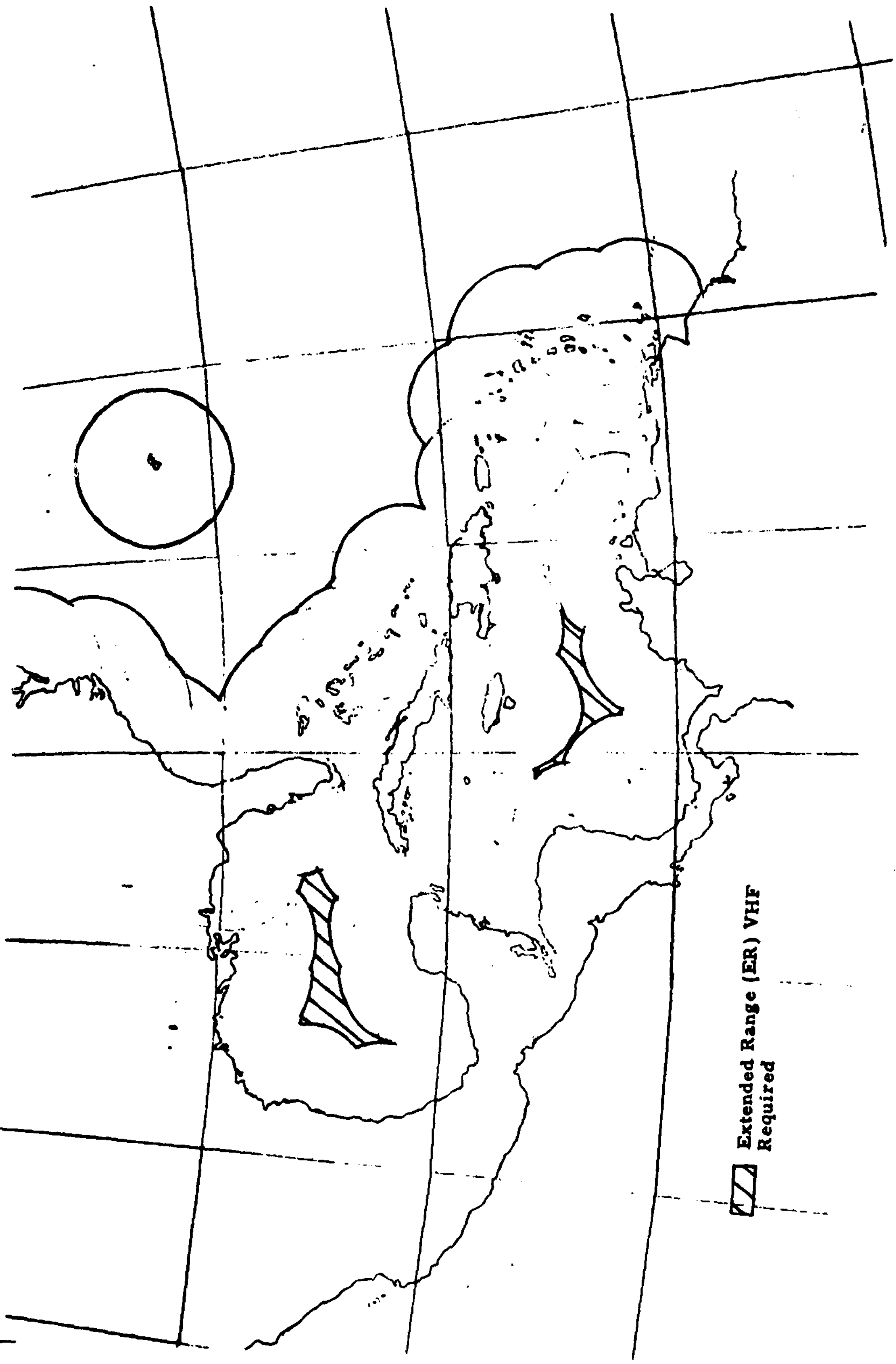


FIGURE 14-3. CAR VHF THEORETICAL COVERAGE AT FL300

Extension of communications improvements into the CAR such as automatic dependent surveillance with network HF data link and voice or with satellite data link and voice require that eleven ATS airspace jurisdictions operate under an integrated plan which would determine the method of communications to be used by aircraft at any given time (i.e., under an integrated operation that coordinates the current VHF and the proposed network HF or satellite direct communications). Further, the method of distribution of air-ground communications to ATC facilities via any of the improvements would need to be defined in the context of the need to coordinate aircraft flying through many, sometimes small, CTA/FIRs. The estimation of the costs of communications in this section is simplified by assuming that each CTA/FIR would have satellite ground-ground communications for linking either the HF or satellite data link and voice system alternatives to these CTA/FIRs for receiving or transmitting air-ground reports from properly equipped aircraft.

14.2 Extension of the Automatic Dependent Surveillance With Network HF Data Link and Voice to the CAR

The NAT improvement descriptions in Section 5 assumed that one ground station would cover part of the CAR, (e.g., with a COM station located near San Juan). Hence, it may be assumed that only one additional station, estimated to cost $1 million would be required to serve all the CAR. In addition, it is assumed that the NAT master control stations would handle the data management for such a system. The maximum load of 50 or so CAR aircraft on the NAT master stations should not significantly effect their cost. Table 14-1 shows the ground station capital and O&M costs spread over three years. In addition it is assumed that ten satellite or other communications links would be required to link ATC facilities to the HF network master control stations. The ATS airspace jurisdictions shown in Figure 14-1 (excluding the San Juan and Miami NAT CTA/FIR whose costs have been included in the NAT estimates) would each have a terminal.

The ATS airspace jurisdictions in the CAR have varying capabilities in terms of communications equipment which could support the links between master stations and ATC facilities. It is assumed that such links could be provided at a cost of $10,000 per month per link. (It should be noted that satellite ground stations can be constructed for $150,000 or less per station. Monthly rental of such a station may be estimated at $1,500. In addition, US domestic satellite links may be leased at costs of approximately $5,000. Therefore, the $10,000 figure appears reasonable. More precise estimates of these costs can only be obtained by examination of communications policies and regulations of individual FIRs.

Table 14-2 shows avionics cost estmates, which are based in part on an estimated fleet size of 400 aircraft in the enroute enivronment (excluding aircraft also using the NAT). Explicit data describing fleet size was not available, and therefore, the fleet size estimate is based

Table 14-1

NETWORK HF DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING THE GROUND STATION NETWORK FOR THE CAR
(1979 US Dollars)

Year	Development and Ground Station Capital Costs	Equipment Maintenance Costs	Ten Interconnection Links
1983	500,000 (feasibility and engineering)		
1984	333,000 (ground station installation)		
1985	333,000 (ground station installation)		
1986	333,000 (ground station installation)		
1987		50,000	2,400,000
1988		50,000	2,400,000
1989		50,000	2,400,000
1990		50,000	2,400,000
1991		50,000	2,400,000
1992		50,000	2,400,000
1993		50,000	2,400,000
1994		50,000	2,400,000
1995		50,000	2,400,000
1996		50,000	2,400,000
1997		50,000	2,400,000
1998		50,000	2,400,000
1999		50,000	2,400,000
2000		50,000	2,400,000
2001		50,000	2,400,000
2002		50,000	2,400,000
2003		50,000	2,400,000
2004		50,000	2,400,000
2005		50,000	2,400,000

Table 14-2

NETWORK HF DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
FOR THE CAR
(1979 US Dollars)

Year	Avionics Cost(1)	New Aircraft Cost(2)	Total	Yearly User Cost ($1/operating hour)
1985	6,897,200	567,600	7,464,800	422,560
1986	6,897,200	567,600	7,464,800	432,440
1987	6,897,200	567,600	7,464,800	442,700
1988		567,600	567,600	453,340
1989		567,600	567,600	463,980
1990		567,600	567,600	475,000
1991		567,600	567,600	486,020
1992		567,600	567,600	497,420
1993		567,600	567,600	509,200
1994		567,600	567,600	521,360
1995		567,600	567,600	533,520
1996		567,600	567,600	546,060
1997		567,600	567,600	558,600
1998		567,600	567,600	571,140
1999		567,600	567,600	584,440
2000		567,600	567,600	597,740
2001		567,600	567,600	611,800
2002		567,600	567,600	625,860
2003		567,600	567,600	639,920
2004		567,600	567,600	654,740
2005		567,600	567,600	669,940
Totals	20,691,600	11,919,600	32,611,200	

(1) Retrofit 160.4 aircraft per year for 3 years at $43,000/year.

(2) Added HF costs only for 13.2 aircraft/year.

on the assumption that the ratio of fleet size to number of high altitude en route flights per day in the CAR is approximately the same in the CAR as in the NAT. The CAR is estimated to have about 250 flights per day, excluding an additional 150 flights that also fly through the NAT (ref. 1). The estimated 1,059 aircraft fleet size and 656 daily costed flights in the NAT in 1979 obtains a ratio of 1.6, which when applied to the 250 daily CAR flights, obtains a 400 aircraft fleet size. The fleet growth rate is assumed to correspond to the increase in the number of flights, which are estimated to grow by 78% by the year 2005 (ref. 1) and is comparable to the NAT growth rate.

14.3 Extension of the Automatic Dependent Surveillance With Satellite Data Link and Voice to the CAR

Table 14-3 shows assumed satellite and ground station costs for the CAR. This table was obtained by assuming that 10 small C-band ground stations would be used to access the NAT system (the San Juan and Miami NAT costs have been allocated to NAT implementation). These stations would have low volume communications and would use C-band channels provided for by the space segment. Such stations might be fabricated and installed over a four year period at a cost of $150,000 each.

The nominal cost of a satellite and launch for the NAT was $4,700,000. A peak load increase of 40 CAR aircraft (versus about 225 aircraft for which the proposed NAT system was designed) will have very little effect on the data flow requirements of the NAT system because NAT satellite improvement costs were dominated by a voice channel. It is probable that this voice channel will be adequate to support CAR aviation needs for the very limited number of flights in the CAR which are not within VHF voice coverage. Each NAT satellite package and launch is allocated an additional $1 million to cover possible increased weight and power requirements for the increased number of transponders and associated components needed for CAR air-ground communication and supporting ground-ground communications. This cost is an 18% increase over NAT estimates based on the estimated number of CAR aircraft using HF SSB.

No additional tracking, telemetry and command costs are needed for the CAR because the NAT master stations are assumed capable of handling communications management functions. A cost of $100,000 per year is allocated to maintaining ground terminals.

Table 14-4 shows avionics costs under the same assumptions discussed in Section 14.2.

Table 14-3

SATELLITE DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE CAR
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance
1985		375,000	100,000
1986	1,000,000 (incremental satellite costs)	375,000	100,000
1987		375,000	100,000
1988	1,000,000 (incremental satellite costs)	375,000	100,000
1989		100,000	
1990		100,000	
1991		100,000	
1992		100,000	
1993	1,000,000 (incremental satellite costs)	100,000	
1994		100,000	
1995	1,000,000 (incremental satellite costs)	100,000	
1996		100,000	
1997		100,000	
1998		100,000	
1999		100,000	
2000	1,000,000 (incremental satellite costs)	100,000	
2001		100,000	
2002	1,000,000 (incremental satellite costs)	100,000	
2003		100,000	
2004		100,000	
2005		100,000	

Table 14-4

AUTOMATIC DEPENDENT SURVEILLANCE WITH
SATELLITE DATA LINK AND VOICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
FOR THE CAR
(1979 US Dollars)

Year	Retrofit Costs (1)	New Fleet Equipment Cost (2)	Total Equipment Cost	Yearly User Cost ($1/operating hour)
1985	8,228,520	660,000	8,888,520	422,560
1986	8,228,520	660,000	8,888,520	432,440
1987	8,228,520	660,000	8,888,520	442,700
1988	0	660,000	660,000	453,340
1989	0	660,000	660,000	463,980
1990	0	660,000	660,000	475,000
1991	0	660,000	660,000	486,020
1992	0	660,000	660,000	497,420
1993	0	660,000	660,000	509,200
1994	0	660,000	660,000	521,360
1995	0	660,000	660,000	533,520
1996	0	660,000	660,000	546,060
1997	0	660,000	660,000	558,600
1998	0	660,000	660,000	571,140
1999	0	660,000	660,000	584,440
2000	0	660,000	660,000	597,740
2001	0	660,000	660,000	611,800
2002	0	660,000	660,000	625,860
2003	0	660,000	660,000	639,920
2004	0	660,000	660,000	654,740
2005	0	660,000	660,000	669,940
Total	24,685,560	17,160,000	41,845,560	

(1) 160.4 aircraft/year at $51,300 per aircraft for 3 years.

(2) 13.2 new aircraft per year at $50,000 per aircraft.

14.4 Separation Assurance Device

Separation assurance in the CAR is assumed to involve avionics cost only. Table 14-5 shows these costs under the same assumptions on avionics cost made in Section 5. Fleet assumptions are the same as those in Section 14.2

14.5 Reference

1. SRI Internaional, "Oceanic Area Improvement Study (OASIS) Volume IV: Caribbean Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, IV (September 1981).

Table 14-5

AIRBORNE SEPARATION ASSURANCE DEVICE
USER COSTS FOR AVIONICS INSTALLATION AND OPERATION
FOR THE CAR
(1979 US Dollars)

Year	Retrofit Cost (1)	New Aircraft Equipment Cost (2)	Total	Yearly User Cost ($1/operating hour)
1985	8,276,640	644,160	8,920,800	422,560
1986	8,276,640	644,160	8,920,800	432,440
1987	8,276,640	644,160	8,920,800	442,700
1988		644,160	644,160	453,340
1989		644,160	644,160	463,980
1990		644,160	644,160	475,000
1991		644,160	644,160	486,020
1992		644,160	644,160	497,420
1993		644,160	644,160	509,200
1994		644,160	644,160	521,360
1995		644,160	644,160	533,520
1996		644,160	644,160	546,060
1997		644,160	644,160	558,600
1998		644,160	644,160	571,140
1999		644,160	644,160	584,440
2000		644,160	644,160	597,740
2001		644,160	644,160	611,800
2002		644,160	644,160	625,860
2003		644,160	644,160	639,920
2004		644,160	644,160	654,740
2005		644,160	644,160	669,940
Total	16,837,800	11,256,960	28,094,760	

(1) Retrofit 160.4 aircraft per year at $51,600 per aircraft.

(2) 13.2 aircraft at $48,800 per aircraft.

15.0 CAR USER FLIGHT COSTS

15.1 Introduction

The CAR does not experience the highly concentrated traffic flows as exist on the OTS in the NAT and ORS in the CEP. Although some relatively dense traffic corridors exist in the CAR, the degree of congestion is less in the CAR than in the NAT or CEP because of the general dispersion of traffic over numerous routes. Because of the expectation of low congestion cost penalties in the CAR relative to the NAT and CEP and because of limited data, the FCM was not applied to the CAR to estimate user flight costs. Instead, a preliminary graphical analysis procedure was used to roughly estimate fuel diversion costs due to potential conflict resolution.

15.2 Flight Diversion Costs

The graphical analysis evaluated closure distances between plotted aircraft trajectories representing a 1979 busy day and estimated potential conflict frequencies. These data were used to estimate the fuel costs of diversion due to conflicts as explained in Appendix E. The fuel diversion costs are estimated for the present system separation minima and for proposed alternative separations.

The current minima basically are 100 nmi laterally, generally 15 min longitudinally but 10 min longitudinally where warranted by navigation facilities, and 2000 ft vertically. It is assumed that the separation minima, and associated potential conflict situations, will be affected by planned secondary radar installatins that would provide complete coverage along the Miami to San Juan traffic corridor and nearby areas. Present plans are proceeding in the implementation of radar facilities at Nassau in the Bahamas, and the US is considering the possibility of implementing a radar facility at Grand Turk Island. This traffic corridor is very busy by CAR standards, and the radar installations in the early 1980s will significantly alleviate congestion in the area. The effect of the planned radar service on congestion costs has been estimated (see Appendix E) and is represented by the 100 nmi/15-10 min/2000 ft Radar (R) fuel diversion cost estimates shown in Table 15-1. The other fuel diversion cost estimates shown in this table represent current separation minima (100 nmi/15-10 min/ 2000 ft) and potential future alternative minima (30 nmi/5 min/2000 ft R and and 15 nmi/2 min/2000 ft R). The designator "R" signifies that the planned radars are assumed to be implemented in the Miami to San Juan traffic corridor and that radar separation minima (e.g., 5 nmi) are assumed to be applied in the area of radar coverage.

Table 15-1

CAR ANNUAL USER FLIGHT O&M DIVERSION COST ESTIMATES

Year	Fuel Cost of Diversion (millions of 1979 U.S. Dollars)			
	100 nmi/ 15-10 min/ 2000 ft	100 nmi/ 15-10 min/ 2000 ft R	30 nmi/ 5 min/ 2000 ft R	15 nmi/ 2 min/ 2000 ft R
1979	0.79	0.39	0.13	0.05
1980	0.83	0.41	0.14	0.06
1981	0.87	0.43	0.15	0.06
1982	0.91	0.45	0.16	0.06
1983	0.96	0.47	0.16	0.07
1984	1.00	0.50	0.17	0.07
1985	1.05	0.52	0.18	0.07
1986	1.10	0.55	0.19	0.08
1987	1.16	0.57	0.20	0.08
1988	1.21	0.60	0.21	0.08
1989	1.27	0.63	0.22	0.09
1990	1.34	0.66	0.23	0.09
1991	1.40	0.69	0.24	0.10
1992	1.47	0.73	0.25	0.10
1993	1.54	0.76	0.26	0.10
1994	1.62	0.80	0.27	0.11
1995	1.69	0.84	0.29	0.12
1996	1.76	0.87	0.30	0.12
1997	1.83	0.91	0.31	0.12
1998	1.91	0.95	0.32	0.13
1999	1.99	0.98	0.34	0.14
2000	2.07	1.02	0.35	0.14
2001	2.15	1.07	0.37	0.15
2002	2.24	1.11	0.38	0.15
2003	2.33	1.15	0.40	0.16
2004	2.42	1.20	0.41	0.16
2005	2.52	1.25	0.43	0.17

The graphical analysis process could only be applied to horizontal conflict situations (e.g., crossing, joining and following aircraft at the same altitude) because available data describing vertical flight profiles in the CAR are limited. Therefore, the cost impact of 1000 ft vertical separation minima is not estimated.

16.0 CAR PROVIDER FACILITIES COSTS

16.1 Introduction

Available information concerning the ATS unit and COM station O&M costs in the CAR is limited, and cost estimates are made in this section based on analogies with NAT operations and on the available data.

16.2 ATS Unit Annual O&M Costs

Estimates of annual O&M costs in 1979 have been included in a present system description report (ref. 1) addressing the CAR-related operations at the Curacao, Habana, Houston, Kingston, Maiquetia, Merida, Miami, Piarco, San Juan, and Santo Domingo ACCs and the Port-au-Prince Flight Information Center (FIC). The estimates were based in part on data provided by some provider authorities and in part on assumptions concerning the level of expenditures. Based on these data, the 1979 ATS facility O&M costs in the CAR are roughly estimated to be $12 million. The O&M costs for present system continuance are assumed to increase at a 2.25% annually compounded growth rate based on a projected 78% CAR traffic increase from 1979 to 2005 (ref. 1).

The ATS facility O&M costs for the automatic dependent surveillance and cooperative independent surveillance potential improvements in the CAR are assumed to follow the same expenditure characteristics as those postulated for the NAT facilities, except that no additional RDT&E program costs are assumed to be required beyond those previously included in the NAT cost estimates in Section 7. The equipment costs are assumed to be $250 thousand per sector as estimated for the NAT, and the CAR provider capital cost estimates are calculated as follows. The ATS units operated about 20 CAR sectors in 1979 with allowance for shared CAR, domestic and NAT responsibilities at various sites. Assuming that automatic dependent surveillance operations could be initiated in 1990 and allowing for the 2.25% annual compound growth rate in sectorization, 26 sectors would be required in 1990 at a cost of $6.5 million as shown in Table 16-1. The 26 sector equipment units are assumed to be purchased in 1987 to allow time for installation and for a two year operational shake-down in 1988 and 1989. Allowing for continued sectorization growth at the 2.25% rate, 3 additional sectors are assumed to be required every five years at a cost of $0.75 million in each of 1995, 2000 and 2005 as shown in Table 16-1.

Similar capital cost estimates are assumed for cooperative independent surveillance except that improvement operations are assumed to be initiated in 1995 with an initial purchase of 29 sector equipment units in 1992 at a cost of $7.25 million, as shown in Table 16-1. (Note:

Table 16-1

CAR ATS UNIT PROVIDER COST ESTIMATES
(Millions of 1979 US Dollars)

	Present System Continuance	Automatic Dependent Surveillance		Independent Cooperative Surveillance	
Year	Annual O&M*	Capital†	Annual O&M*	Capital†	Annual O&M*
1979	12.0				
1980	12.3				
1981	12.5				
1982	12.8				
1983	13.1				
1984	13.4				
1985	13.7				
1986	14.0				
1987	14.3	6.5	14.3		
1988	14.7		14.7		
1989	15.0		15.0		
1990	15.3		15.3		
1991	15.7		15.7		
1992	16.0		16.0	7.25	16.0
1993	16.4		16.4		16.4
1994	16.8		16.8		16.8
1995	17.1	0.75	17.1		17.1
1996	17.5		17.5		17.5
1997	17.9		17.9		17.9
1998	18.3		18.3		18.3
1999	18.7		18.7		18.7
2000	19.1	0.75	19.1	0.75	19.1
2001	19.6		19.6		19.6
2002	20.0		20.0		20.0
2003	20.5		20.5		20.5
2004	20.9		20.9		20.9
2005	21.4	0.75	21.4	0.75	21.4

*Indicated values are based on a 2.25% annual compound growth rate starting with the present system 1979 cost.

†Indicated values include a $6.5 million (or $7.25 million) initial equipment purchase cost and $0.75 million periodic equipment expansion costs; all capital costs assume a 20 year recovery life.

These O&M cost estimates are provided for information purposes since the cooperative independent surveillance operation in the CAR is not explicitly addressed.)

In accordance with the discussions presented in Section 7, the ATS annual O&M costs for the automatic dependent and independent cooperative surveillance system are assumed to be the same as those for present system continuance as shown in Table 16-1. These data represent the estimated expenses that would be required if the representative systems were in operation in the year indicated.

16.3 COM Station Annual O&M Costs

Cost data are not available in sufficient detail to describe O&M expenditures for COM stations in the CAR. To provide a gross estimate of costs, O&M expenditures are approximated using the NAT cost estimates for analogy, as follows: The CAR estimated 1979 ATS facility O&M cost ($12 million) is on the order of half the corresponding NAT estimate. Using the assumption that COM costs are proportional to ATS costs, halving the NAT 1979 COM O&M cost (almost $10 million) yields an estimate of about $5 million for 1979 COM O&M costs; however, because of the lack of data, this estimate is recognized to be a rough approximation. The present system O&M costs are assumed to increase at the 2.25% compound annual growth rate defined in the preceding paragraphs.

Allowing for the need to provide some residual HF voice service in the case of implementing HF data link or satellite data link and voice communication services, the annual COM station O&M costs for these services, and for the network HF data link and voice alternative or the satellite data link and voice alternative are assumed to be the same as those for present system continuance. It was assumed that the current HF voice communication facilities would provide the residual service in support of the ATS units. The resulting annual costs shown in Table 16-2 represent the estimated expenses that would be required if the respective systems were in operation in the year indicated, assuming that automatic dependent surveillance (with network HF or satellite data link) could be implemented in 1990 and independent cooperative surveillance could be implemented in 1995 with appropriate lead time for system establishment.

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume IV: Caribbean Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, IV (September 1981).

Table 16-2

CAR COM FACILITY ANNUAL O&M COST ESTIMATES
(Millions of 1979 US Dollars)

Year	Present System Continuance[*]	Network HF Data Link & Voice[†]	Satellite Data Link and Voice or Multiple Satellite[†]
1979	5.0		
1980	5.1		
1981	5.2		
1982	5.3		
1983	5.5		
1984	5.6		
1985	5.7		
1986	5.8		
1987	6.0	6.0	
1988	6.1	6.1	
1989	6.2	6.2	
1990	6.4	6.4	6.4
1991	6.5	6.5	6.5
1992	6.7	6.7	6.7
1993	6.8	6.8	6.8
1994	7.0	7.0	7.0
1995	7.1	7.1	7.1
1996	7.3	7.3	7.3
1997	7.5	7.5	7.5
1998	7.6	7.6	7.6
1999	7.8	7.8	7.8
2000	8.0	8.0	8.0
2001	8.2	8.2	8.2
2002	8.3	8.3	8.3
2003	8.5	8.5	8.5
2004	8.7	8.7	8.7
2005	8.9	8.9	8.9

[*] Indicated values are based on a 2.25% compound annual growth rate.

[†] Each indicated value is equal to the corresponding present system continuance costs.

17.0 CAR IMPROVEMENT CONFIGURATIONS AND COST COMPARISONS

17.1 Introduction

The CAR potential improvement configurations addressed in this section are extensions of some of the primary improvements considered for the NAT. The selected configurations are presented in this section and their costs are compared.

17.2 Potential Improvement Configurations

The following preliminary set of improvement configurations assumes that each configuration is developed by evolutionary improvement to the 1979 present system and its continuance; the values in parenthesis describe the most advanced separation minima achieved by the configuration in the year indicated, and the designator "R" signifies radar coverage in the Miami to San Juan traffic corridor:

(1) Configuration 1. Baseline, HF SSB voice, 100 nmi/15-10 min/2000 ft through 1982, 100 nmi/15-10 min/2000 ft with Expanded Radar (R) coverage in 1983 through 2005

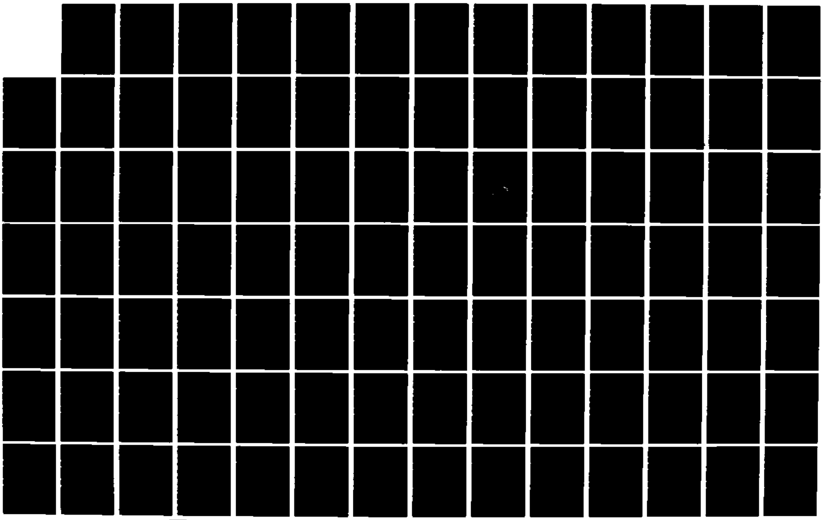
(2) Configuration 2. Airborne Separation Assurance Device with 100% avionics capital cost allocation, HF SSB voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005

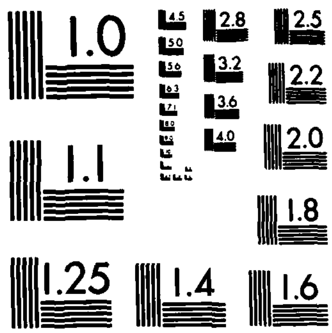
(3) Configuration 3. Airborne Separation Assurance Device With 50% Avionics Capital Cost Allocation, HF SSB voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005

(4) Configuration 4. Automatic Dependent Surveillance with Network HF Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005

(5) Configuration 5. Automatic Dependent Surveillance with Satellite Data Link and Voice, MNPS (Improved), 30 nmi/5 min/2000 ft R in 1990 through 2005

AD-A123 896 OCEANIC AREA SYSTEM IMPROVEMENT STUDY (OASIS) VOLUME I 4/5
EXECUTIVE SUMMARY A..(U) SRI INTERNATIONAL MENLO PARK
CA G J COULURIS ET AL. SEP 81 OASIS FAA-EM-81-17-1
UNCLASSIFIED DOT-FA79WA-4265 F/G 17/7 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The specific evolution of separation minima for each configuration is specified in Table 17-1. The baseline and alternative configurations assume establishment of radar operations in the Miami to San Juan traffic corridor in 1983. The separation minima schedules corresponding to each improvement conform to the analogous separations defined for the NAT configurations.

The provider and user capital and O&M cost estimates for each configuration are shown in Tables 17-2 through 17-6. These data are based on the cost estimates given in Sections 14, 15, and 16 and assume that the respective improvements are coordinated with and dependent on similar improvements in the NAT. The preliminary system design and development costs for the improvements are assumed to be required for NAT implementation and are not allocated to the CAR. The establishment of satellite air-ground data link and voice in the CAR is assumed to be provided by expansion of the communications channel capabilities of the NAT system without duplication of the entire cost of the NAT space segment. Similarly, implementation of the CAR network HF or satellite data link and voice ground stations is assumed to be coordinated with NAT facilities (i.e., at San Juan) to avoid redundant implementation costs.

The capital, O&M, and total costs estimated for each configuration during the 1979 through 2005 time period are summarized in Table 17-7.

17.3 Configuration Cost Comparisons

The 1979 present values of the user and provider capital, O&M, and total outlays during the 1979 through 2005 time period are shown in Tables 17-8 and, with costs integrated with respect to user and provider costs, in Table 17-9 for each configuration. The present values are based on the same inflation and discount rate assumptions applied to the NAT.

The 1979 present values of the net cost differences relative to the baseline configuration are presented in Table 17-10 and, with costs integrated with respect to user and provider costs, in Table 17-11 for each configuration. Table 17-11 shows that net cost losses are associated with the indicated improvements. In these cases, the modest reductions in user flight diversion cost are not sufficient to counterbalance the improvements costs, and net cost losses result.

However, the potential improvements should not be dismissed simply on the basis of apparent economic liability because: (1) the improvements, (especially the separation assurance which is shown in Table 17-11 to have less of a cost loss than the other improvements) would support enhanced separation assurance services, particularly in one CAR flight information region which currently does not provide air traffic control service; (2) one or more of the improvements might be economically preferred in comparison with the alternative of expanding line-of-site facilities; (3) The user flight costs were roughly estimated and

better estimates might improve the attractiveness of one or more of the improvements. Note that, although the 1000 ft vertical separation above FL 290 improvement was not analyzed, this improvement is expected to achieve net total cost savings in the CAR based on the results obtained for analogous improvement operations in the NAT and CEP.

Table 17-1

CAR POTENTIAL IMPROVEMENT CONFIGURATION

Configuration Components*	Separation Minima Evolution*	Support Requirements*
Configuration 1. Baseline	100 nmi/15-10 min/2000 ft: 1979-1982 100 nmi/15-10 min/2000 ft R: 1983-2005	HF SSB + Expanded radar coverage
Configuration 2. Baseline + Separation Assurance Device With 100% Avionics Capital Cost Allocation	Baseline separation minima: 1979-1988 30 nmi/5 min/2000 ft R: 1990-2005	HF SSB, Expanded radar + MNPS (Improved)
Configuration 3. Baseline + Separation Assurance Device With 50% Avionics Capital Cost Allocation	Baseline separation minima: 1979-1988 30 nmi/5 min/2000 ft R: 1990-2005	HF SSB, Expanded radar + MNPS (Improved)
Configuration 4. Baseline + ADS With Network HF Data Link and Voice	Baseline separation minima: 1979-1989 30 nmi/5 min/2000 ft R: 1990-2005	HF SSB, Expanded radar + MNPS (Improved); Direct air-ground and Advanced ATC information processing
Configuration 5. Baseline + ADS With Satellite Data Link and Voice	Baseline separation minima: 1979-1989 30 nmi/5 min/2000 ft R: 1990-2005	HF SSB, Expanded radar + MNPS (Improved); Direct air-ground and Advanced ATC information processing

*HF SSB = High-frequency single sideband pilot-radio operator air-ground voice communication
Direct air-ground = Direct pilot-controller data link or voice link or both.
Advanced ATC information processing = Automated ATC data handling, controller displays, and associated advanced ATC automation
MNPS = Minimum Navigation Performance Specification
PS = Performance Specification
ADS = Automatic Dependent Surveillance
Network HF = Network HF data link and voice
Simple Network HF = Simple Network HF data link and voice
Satellite = Satellite data link and voice
Multiple Satellite = Multiple satellite data link and voice
Separation Assurance Device = Airborne separation assurance device
R = Expanded radar operations in Miami to San Juan traffic corridor

TABLE 17-2
COST SUMMARY FOR CAR CONFIGURATION 1:
BASELINE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	5.00	12.00	17.00	0.000	0.000	0.000	0.79	0.00	0.79	17.000	0.790	17.790	1979
1980	0.000	0.000	0.000	5.10	12.30	17.40	0.000	0.000	0.000	0.83	0.00	0.83	17.400	0.830	18.230	1980
1981	0.000	0.000	0.000	5.20	12.50	17.70	0.000	0.000	0.000	0.87	0.00	0.87	17.700	0.870	18.570	1981
1982	0.000	0.000	0.000	5.30	12.80	18.10	0.000	0.000	0.000	0.91	0.00	0.91	18.100	0.910	19.010	1982
1983	0.000	0.000	0.000	5.50	13.10	18.60	0.000	0.000	0.000	0.47	0.00	0.47	18.600	0.470	19.070	1983
1984	0.000	0.000	0.000	5.60	13.40	19.00	0.000	0.000	0.000	0.50	0.00	0.50	19.000	0.500	19.500	1984
1985	0.000	0.000	0.000	5.70	13.70	19.40	0.000	0.000	0.000	0.52	0.00	0.52	19.400	0.520	19.920	1985
1986	0.000	0.000	0.000	5.80	14.00	19.80	0.000	0.000	0.000	0.55	0.00	0.55	19.800	0.550	20.350	1986
1987	0.000	0.000	0.000	6.00	14.30	20.30	0.000	0.000	0.000	0.57	0.00	0.57	20.300	0.570	20.870	1987
1988	0.000	0.000	0.000	6.10	14.70	20.80	0.000	0.000	0.000	0.60	0.00	0.60	20.800	0.600	21.400	1988
1989	0.000	0.000	0.000	6.20	15.00	21.20	0.000	0.000	0.000	0.63	0.00	0.63	21.200	0.630	21.830	1989
1990	0.000	0.000	0.000	6.40	15.30	21.70	0.000	0.000	0.000	0.66	0.00	0.66	21.700	0.660	22.360	1990
1991	0.000	0.000	0.000	6.50	15.70	22.20	0.000	0.000	0.000	0.69	0.00	0.69	22.200	0.690	22.890	1991
1992	6.500	0.000	6.500	6.70	16.00	22.70	0.000	0.000	0.000	0.73	0.00	0.73	29.200	0.730	29.930	1992
1993	0.000	0.000	0.000	6.80	16.40	23.20	0.000	0.000	0.000	0.76	0.00	0.76	23.200	0.760	23.960	1993
1994	0.000	0.000	0.000	7.00	16.80	23.80	0.000	0.000	0.000	0.80	0.00	0.80	23.800	0.800	24.600	1994
1995	0.000	0.000	0.000	7.10	17.10	24.20	0.000	0.000	0.000	0.84	0.00	0.84	24.200	0.840	25.040	1995
1996	0.000	0.000	0.000	7.30	17.50	24.80	0.000	0.000	0.000	0.87	0.00	0.87	24.800	0.870	25.670	1996
1997	0.000	0.000	0.000	7.50	17.90	25.40	0.000	0.000	0.000	0.91	0.00	0.91	25.400	0.910	26.310	1997
1998	0.000	0.000	0.000	7.60	18.30	25.90	0.000	0.000	0.000	0.95	0.00	0.95	25.900	0.950	26.850	1998
1999	0.000	0.000	0.000	7.80	18.70	26.50	0.000	0.000	0.000	0.98	0.00	0.98	26.500	0.980	27.480	1999
2000	0.750	0.000	0.750	8.00	19.10	27.10	0.000	0.000	0.000	1.02	0.00	1.02	27.850	1.020	28.870	2000
2001	0.000	0.000	0.000	8.20	19.60	27.80	0.000	0.000	0.000	1.07	0.00	1.07	27.800	1.070	28.870	2001
2002	0.000	0.000	0.000	8.30	20.00	28.30	0.000	0.000	0.000	1.11	0.00	1.11	28.300	1.110	29.410	2002
2003	0.000	0.000	0.000	8.50	20.50	29.00	0.000	0.000	0.000	1.15	0.00	1.15	29.000	1.150	30.150	2003
2004	0.000	0.000	0.000	8.70	20.90	29.60	0.000	0.000	0.000	1.20	0.00	1.20	29.600	1.200	30.800	2004
2005	0.750	0.000	0.750	8.90	21.40	30.30	0.000	0.000	0.000	1.25	0.00	1.25	31.050	1.250	32.300	2005

TABLE 17-3
COST SUMMARY FOR CAR CONFIGURATION 2:
SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	5.00	12.00	17.00	0.000	0.000	0.000	0.79	0.00	0.79	17.000	0.790	17.790	1979
1980	0.000	0.000	0.000	5.10	12.30	17.40	0.000	0.000	0.000	0.83	0.00	0.83	17.400	0.830	18.230	1980
1981	0.000	0.000	0.000	5.20	12.50	17.70	0.000	0.000	0.000	0.87	0.00	0.87	17.700	0.870	18.570	1981
1982	0.000	0.000	0.000	5.30	12.80	18.10	0.000	0.000	0.000	0.91	0.00	0.91	18.100	0.910	19.010	1982
1983	0.000	0.000	0.000	5.50	13.10	18.60	0.000	0.000	0.000	0.47	0.00	0.47	18.600	0.470	19.070	1983
1984	0.000	0.000	0.000	5.60	13.40	19.00	0.000	0.000	0.000	0 50	0.00	0.50	19.000	0.500	19.500	1984
1985	0.000	0.000	0.000	5.70	13.70	19.40	8.921	0.423	9.344	.52	0.00	0.52	19.400	9.864	29.264	1985
1986	0.000	0.000	0.000	5.80	14.00	19.80	8.921	0.432	9.353	0.55	0.00	0.55	19.800	9.903	29.703	1986
1987	0.000	0.000	0.000	6.00	14.30	20.30	8.921	0.443	9.364	0.57	0.00	0.57	20.300	9.934	30.234	1987
1988	0.000	0.000	0.000	6.10	14.70	20.80	0.644	0.453	1.097	0.60	0.00	0.60	20.800	1.697	22.497	1988
1989	0.000	0.000	0.000	6.20	15.00	21.20	0.644	0.464	1.108	0.63	0.00	0.63	21.200	1.738	22.938	1989
1990	0.000	0.000	0.000	6.40	15.30	21.70	0.644	0.475	1.119	0.23	0.00	0.23	21.700	1.349	23.049	1990
1991	0.000	0.000	0.000	6.50	15.70	22.20	0.644	0.486	1.130	0.24	0.00	0.24	22.200	1.370	23.576	1991
1992	6.500	0.000	6.500	6.70	16.00	22.70	0.644	0.497	1.141	0.25	0.00	0.25	29.200	1.391	30.591	1992
1993	0.000	0.000	0.000	6.80	16.40	23.20	0.644	0.509	1.153	0.26	0.00	0.26	23.200	1.413	24.613	1993
1994	0.000	0.000	0.000	7.00	16.80	23.80	0.644	0.521	1.165	0.27	0.00	0.27	23.800	1.435	25.235	1994
1995	0.000	0.000	0.000	7.10	17.10	24.20	0.644	0.534	1.178	0.29	0.00	0.29	24.200	1.468	25.668	1995
1996	0.000	0.000	0.000	7.30	17.50	24.80	0.644	0.546	1.190	0.30	0.00	0.30	24.800	1.490	26.290	1996
1997	0.000	0.000	0.000	7.50	17.90	25.40	0.644	0.559	1.203	0.31	0.00	0.31	25.400	1.513	26.913	1997
1998	0.000	0.000	0.000	7.60	18.30	25.90	0.644	0.571	1.215	0.32	0.00	0.32	25.900	1.535	27.435	1998
1999	0.000	0.000	0.000	7.80	18.70	26.50	0.644	0.584	1.228	0.34	0.00	0.34	26.500	1.568	28.068	1999
2000	0.750	0.000	0.750	8.00	19.10	27.10	0.644	0.598	1.242	0.35	0.00	0.35	27.850	1.592	29.442	2000
2001	0.000	0.000	0.000	8.20	19.60	27.80	0.644	0.612	1.256	0.37	0.00	0.37	27.800	1.626	29.426	2001
2002	0.000	0.000	0.000	8.30	20.00	28.30	0.644	0.626	1.270	0.38	0.00	0.38	28.300	1.650	29.950	2002
2003	0.000	0.000	0.000	8.50	20.50	29.00	0.644	0.640	1.284	0.40	0.00	0.40	29.000	1.684	30.684	2003
2004	0.000	0.000	0.000	8.70	20.90	29.60	0.644	0.655	1.299	0.41	0.00	0.41	29.600	1.709	31.309	2004
2005	0.750	0.000	0.750	8.90	21.40	30.30	0.644	0.670	1.314	0.43	0.00	0.43	31.050	1.744	32.794	2005

TABLE 17-4

COST SUMMARY FOR CAR CONFIGURATION 3:
SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	5.00	12.00	17.00	0.000	0.000	0.000	0.79	0.00	0.79	17.300	0.790	17.790	1979
1980	0.000	0.000	0.000	5.10	12.30	17.40	0.000	0.000	0.000	0.83	0.00	0.83	17.400	0.830	18.230	1980
1981	0.000	0.000	0.000	5.20	12.50	17.70	0.000	0.000	0.000	0.87	0.00	0.87	17.700	0.870	18.570	1981
1982	0.000	0.000	0.000	5.30	12.80	18.10	0.000	0.000	0.000	0.91	0.00	0.91	18.100	0.910	19.010	1982
1983	0.000	0.000	0.000	5.50	13.10	18.60	0.000	0.000	0.000	0.47	0.00	0.47	18.600	0.470	19.070	1983
1984	0.000	0.000	0.000	5.60	13.40	19.00	0.000	0.000	0.000	0.50	0.00	0.50	19.000	0.500	19.500	1984
1985	0.000	0.000	0.000	5.70	13.70	19.40	4.461	0.423	4.884	0.52	0.00	0.52	19.400	5.404	24.804	1985
1986	0.000	0.000	0.000	5.80	14.00	19.80	4.461	0.432	4.893	0.55	0.00	0.55	19.800	5.443	25.243	1986
1987	0.000	0.000	0.000	6.00	14.30	20.30	4.461	0.443	4.904	0.57	0.00	0.57	20.300	5.474	25.774	1987
1988	0.000	0.000	0.000	6.10	14.70	20.80	0.322	0.453	0.775	0.60	0.00	0.60	20.800	1.375	22.175	1988
1989	0.000	0.000	0.000	6.20	15.00	21.20	0.322	0.464	0.786	0.63	0.00	0.63	21.200	1.416	22.616	1989
1990	0.000	0.000	0.000	6.40	15.30	21.70	0.322	0.475	0.797	0.23	0.00	0.23	21.700	1.027	22.727	1990
1991	0.000	0.000	0.000	6.50	15.70	22.20	0.322	0.486	0.808	0.24	0.00	0.24	22.200	1.048	23.248	1991
1992	6.500	0.000	6.500	6.70	16.00	22.70	0.322	0.497	0.819	0.25	0.00	0.25	29.200	1.069	30.269	1992
1993	0.000	0.000	0.000	6.80	16.40	23.20	0.322	0.509	0.831	0.26	0.00	0.26	23.200	1.091	24.291	1993
1994	0.000	0.000	0.000	7.00	16.80	23.80	0.322	0.521	0.843	0.27	0.00	0.27	23.800	1.113	24.913	1994
1995	0.000	0.000	0.000	7.10	17.10	24.20	0.322	0.534	0.856	0.29	0.00	0.29	24.200	1.146	25.346	1995
1996	0.000	0.000	0.000	7.30	17.50	24.80	0.322	0.546	0.868	0.30	0.00	0.30	24.800	1.168	25.968	1996
1997	0.000	0.000	0.000	7.50	17.90	25.40	0.322	0.559	0.881	0.31	0.00	0.31	25.400	1.191	26.591	1997
1998	0.000	0.000	0.000	7.60	18.30	25.90	0.322	0.571	0.893	0.32	0.00	0.32	25.900	1.213	27.113	1998
1999	0.000	0.000	0.000	7.80	18.70	26.50	0.322	0.584	0.906	0.34	0.00	0.34	26.500	1.246	27.746	1999
2000	0.750	0.000	0.750	8.00	19.10	27.10	0.322	0.598	0.920	0.35	0.00	0.35	27.850	1.270	29.120	2000
2001	0.000	0.000	0.000	8.20	19.60	27.80	0.322	0.612	0.934	0.37	0.00	0.37	27.800	1.304	29.104	2001
2002	0.000	0.000	0.000	8.30	20.00	28.30	0.322	0.626	0.948	0.38	0.00	0.38	28.300	1.328	29.628	2002
2003	0.000	0.000	0.000	8.50	20.50	29.00	0.322	0.640	0.962	0.40	0.00	0.40	29.000	1.362	30.362	2003
2004	0.000	0.000	0.000	8.70	20.90	29.60	0.322	0.655	0.977	0.41	0.00	0.41	29.600	1.387	30.987	2004
2005	0.750	0.000	0.750	8.90	21.40	30.30	0.322	0.670	0.992	0.43	0.00	0.43	31.050	1.422	32.472	2005

TABLE 17-5

COST SUMMARY FOR CAR CONFIGURATION 4:
AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

YEAR	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			YEAR
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1979	0.000	0.000	0.000	5.00	12.00	17.00	0.000	0.000	0.000	0.79	0.00	0.79	17.000	0.790	17.790	1979
1980	0.000	0.000	0.000	5.10	12.30	17.40	0.000	0.000	0.000	0.83	0.00	0.83	17.400	0.830	18.230	1980
1981	0.000	0.000	0.000	5.20	12.50	17.70	0.000	0.000	0.000	0.87	0.00	0.87	17.700	0.870	18.570	1981
1982	0.000	0.000	0.000	5.30	12.80	18.10	0.000	0.000	0.000	0.91	0.00	0.91	18.100	0.910	19.010	1982
1983	0.500	0.000	0.500	5.50	13.10	18.60	0.000	0.000	0.000	0.47	0.00	0.47	19.100	0.470	19.570	1983
1984	0.333	0.000	0.333	5.60	13.40	19.00	0.000	0.000	0.000	0.50	0.00	0.50	19.333	0.500	19.833	1984
1985	0.333	0.000	0.333	5.70	13.70	19.40	7.465	0.423	7.888	0.52	0.00	0.52	19.733	8.408	28.141	1985
1986	0.333	0.000	0.333	5.80	14.00	19.80	7.465	0.432	7.897	0.55	0.00	0.55	20.133	8.447	28.580	1986
1987	0.000	2.450	2.450	6.00	14.30	20.30	7.465	0.443	7.908	0.57	0.00	0.57	22.750	8.478	31.228	1987
1988	0.000	2.450	2.450	6.10	14.70	20.80	0.568	0.453	1.021	0.60	0.00	0.60	23.250	1.621	24.871	1988
1989	0.000	2.450	2.450	6.20	15.00	21.20	0.568	0.464	1.032	0.63	0.00	0.63	23.650	1.662	25.312	1989
1990	0.000	2.450	2.450	6.40	15.30	21.70	0.568	0.475	1.043	0.23	0.00	0.23	24.150	1.273	25.423	1990
1991	0.000	2.450	2.450	6.50	15.70	22.20	0.568	0.486	1.054	0.24	0.00	0.24	24.650	1.294	25.944	1991
1992	0.000	2.450	2.450	6.70	16.00	22.70	0.568	0.497	1.065	0.25	0.00	0.25	25.150	1.315	26.465	1992
1993	0.000	2.450	2.450	6.80	16.40	23.20	0.568	0.509	1.077	0.26	0.00	0.26	25.650	1.337	26.987	1993
1994	0.000	2.450	2.450	7.00	16.80	23.80	0.568	0.521	1.089	0.27	0.00	0.27	26.250	1.359	27.609	1994
1995	0.000	2.450	2.450	7.10	17.10	24.20	0.568	0.534	1.102	0.29	0.00	0.29	26.650	1.392	28.042	1995
1996	0.000	2.450	2.450	7.30	17.50	24.80	0.568	0.546	1.114	0.30	0.00	0.30	27.250	1.414	28.664	1996
1997	0.000	2.450	2.450	7.50	17.90	25.40	0.568	0.559	1.127	0.31	0.00	0.31	27.850	1.437	29.287	1997
1998	0.000	2.450	2.450	7.60	18.30	25.90	0.568	0.571	1.139	0.32	0.00	0.32	28.350	1.459	29.809	1998
1999	0.000	2.450	2.450	7.80	18.70	26.50	0.568	0.584	1.152	0.34	0.00	0.34	28.950	1.492	30.442	1999
2000	0.000	2.450	2.450	8.00	19.10	27.10	0.568	0.598	1.166	0.35	0.00	0.35	29.550	1.516	31.066	2000
2001	0.000	2.450	2.450	8.20	19.60	27.80	0.568	0.612	1.180	0.37	0.00	0.37	30.250	1.550	31.800	2001
2002	0.000	2.450	2.450	8.30	20.00	28.30	0.568	0.626	1.194	0.38	0.00	0.38	30.750	1.574	32.324	2002
2003	0.000	2.450	2.450	8.50	20.50	29.00	0.568	0.640	1.208	0.40	0.00	0.40	31.450	1.608	33.058	2003
2004	0.000	2.450	2.450	8.70	20.90	29.60	0.568	0.655	1.223	0.41	0.00	0.41	32.050	1.633	33.683	2004
2005	0.000	2.450	2.450	8.90	21.40	30.30	0.568	0.670	1.238	0.43	0.00	0.43	32.750	1.668	34.418	2005

TABLE 17-6
COST SUMMARY FOR CAR CONFIGURATION 5:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER			
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR
1979	0.000	0.000	0.000	5.00	12.00	17.00	0.000	0.000	0.000	0.79	0.00	0.79	17.000	0.790	17.790	1979
1980	0.000	0.000	0.000	5.10	12.30	17.40	0.000	0.000	0.000	0.83	0.00	0.83	17.400	0.830	18.230	1980
1981	0.000	0.000	0.000	5.20	12.50	17.70	0.000	0.000	0.000	0.87	0.00	0.87	17.700	0.870	18.570	1981
1982	0.000	0.000	0.000	5.30	12.80	18.10	0.000	0.000	0.000	0.91	0.00	0.91	18.100	0.910	19.010	1982
1983	0.000	0.000	0.000	5.50	13.10	18.60	0.000	0.000	0.000	0.47	0.00	0.47	18.600	0.470	19.070	1983
1984	0.000	0.000	0.000	5.60	13.40	19.00	0.000	0.000	0.000	0.50	0.00	0.50	19.000	0.500	19.500	1984
1985	0.375	0.100	0.475	5.70	13.70	19.40	8.889	0.423	9.312	0.52	0.00	0.52	19.875	9.832	29.707	1985
1986	1.375	0.100	1.475	5.80	14.00	19.80	8.889	0.432	9.321	0.55	0.00	0.55	21.275	9.871	31.146	1986
1987	0.375	0.100	0.475	6.00	14.30	20.30	8.889	0.443	9.332	0.57	0.00	0.57	20.775	9.902	30.677	1987
1988	1.375	0.100	1.475	6.10	14.70	20.80	0.660	0.453	1.113	0.60	0.00	0.60	22.275	1.713	23.988	1988
1989	0.000	0.100	0.100	6.20	15.00	21.20	0.660	0.464	1.124	0.63	0.00	0.63	21.300	1.754	23.054	1989
1990	0.000	0.100	0.100	6.40	15.30	21.70	0.660	0.475	1.135	0.23	0.00	0.23	21.800	1.365	23.165	1990
1991	0.000	0.100	0.100	6.50	15.70	22.20	0.660	0.486	1.146	0.24	0.00	0.24	22.300	1.386	23.686	1991
1992	0.000	0.100	0.100	6.70	16.00	22.70	0.660	0.497	1.157	0.25	0.00	0.25	22.800	1.407	24.207	1992
1993	1.000	0.100	1.100	6.80	16.40	23.20	0.660	0.509	1.169	0.26	0.00	0.26	24.300	1.429	25.729	1993
1994	0.000	0.100	0.100	7.00	16.80	23.80	0.660	0.521	1.181	0.27	0.00	0.27	23.900	1.451	25.351	1994
1995	1.000	0.100	1.100	7.10	17.10	24.20	0.660	0.534	1.194	0.29	0.00	0.29	25.300	1.484	26.784	1995
1996	0.000	0.100	0.100	7.30	17.50	24.80	0.660	0.546	1.206	0.30	0.00	0.30	24.900	1.506	26.406	1996
1997	0.000	0.100	0.100	7.50	17.90	25.40	0.660	0.559	1.219	0.31	0.00	0.31	25.500	1.529	27.029	1997
1998	0.000	0.100	0.100	7.60	18.30	25.90	0.660	0.571	1.231	0.32	0.00	0.32	26.000	1.551	27.551	1998
1999	0.000	0.100	0.100	7.80	18.70	26.50	0.660	0.584	1.244	0.34	0.00	0.34	26.600	1.584	28.184	1999
2000	1.000	0.100	1.100	8.00	19.10	27.10	0.660	0.598	1.258	0.35	0.00	0.35	28.200	1.608	29.808	2000
2001	0.000	0.100	0.100	8.20	19.60	27.80	0.660	0.612	1.272	0.37	0.00	0.37	27.900	1.642	29.542	2001
2002	1.000	0.100	1.100	8.30	20.00	28.30	0.660	0.626	1.286	0.38	0.00	0.38	29.400	1.666	31.066	2002
2003	0.000	0.100	0.100	8.50	20.50	29.00	0.660	0.640	1.300	0.40	0.00	0.40	29.100	1.700	30.800	2003
2004	0.000	0.100	0.100	8.70	20.90	29.60	0.660	0.655	1.315	0.41	0.00	0.41	29.700	1.725	31.425	2004
2005	0.000	0.100	0.100	8.90	21.40	30.30	0.660	0.670	1.330	0.43	0.00	0.43	30.400	1.760	32.160	2005

TABLE 17-7

COST SUMMARY TOTALS OVER ALL YEARS FOR ALL CAR CONFIGURATIONS

(1979 US $ MILLIONS)

CONFIG URATION	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			CONFIG URATION
	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	
1	0.000	0.000	0.000	182.80	439.00	621.80	0.000	0.000	0.000	22.230	0.000	22.230	629.798	22.230	652.028	1
2	0.000	0.000	0.000	182.80	439.00	621.80	38.355	11.298	49.653	12.390	0.000	12.390	629.798	62.043	691.841	2
3	0.000	0.000	0.000	182.80	439.00	621.80	19.179	11.298	30.477	12.390	0.000	12.390	629.798	42.867	672.664	3
4	1.499	46.550	48.049	182.80	439.00	621.80	32.619	11.298	43.917	12.390	0.000	12.390	669.847	56.307	726.154	4
5	7.500	2.100	9.600	182.80	439.00	621.80	38.547	11.298	49.845	12.390	0.000	12.390	631.398	62.235	693.632	5

ALTER-NATIVE NUMBER	ALTER-NATIVE NAME
1	BASELINE
2	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
3	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
4	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
5	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 17-8

PRESENT VALUE COST SUMMARY TOTALS OVER ALL YEARS FOR ALL CAR CONFIGURATIONS

(1979 DISCOUNTED US $ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			
CONFIG URATION	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	CONFIG URATION
1	4.	0.	4.	142.	341.	483.	0.	0.	0.	17.	0.	17.	487.	17.	504.	1
2	4.	0.	4.	142.	341.	483.	24.	6.	30.	10.	0.	10.	487.	41.	528.	2
3	4.	0.	4.	142.	341.	483.	12.	6.	18.	10.	0.	10.	487.	29.	515.	3
4	1.	34.	36.	142.	341.	483.	20.	6.	27.	10.	0.	10.	518.	37.	555.	4
5	5.	2.	7.	142.	341.	483.	24.	6.	30.	10.	0.	10.	490.	41.	531.	5

ALTER-NATIVE NUMBER	ALTER-NATIVE NAME
1	BASELINE
2	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
3	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
4	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
5	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 17-9
PRESENT VALUE 1979-2005 CAR CONFIGURATIONS COSTS
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIG-URATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	17.	17.	4.	483.	487.	4.	500.	504.	BASELINE
2	24.	17.	41.	4.	483.	487.	28.	499.	528.	SEP AS DEV, 100% AVIONICS COST
3	12.	17.	29.	4.	483.	487.	16.	499.	515.	SEP AS DEV, 50% AVIONICS COST
4	20.	17.	37.	1.	517.	518.	22.	534.	555.	ADS WITH NETWORK HF
5	24.	17.	41.	5.	484.	490.	30.	501.	531.	ADS WITH SAT

TABLE 17-10

PRESENT VALUE NET SAVINGS TOTALS OVER ALL YEARS FOR EACH CAR CONFIGURATION

(1979 DISCOUNTED US $ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER + USER			
CONFIG URATION	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	CONFIG URATION
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1
2	0.	0.	0.	0.	0.	0.	-24.	-6.	-30.	7.	0.	7.	0.	-24.	-24.	2
3	0.	0.	0.	0.	0.	0.	-12.	-6.	-18.	7.	0.	7.	0.	-11.	-11.	3
4	3.	-34.	-32.	0.	0.	0.	-20.	-6.	-27.	7.	0.	7.	-32.	-20.	-51.	4
5	-2.	-2.	-3.	0.	0.	0.	-24.	-6.	-30.	7.	0.	7.	-3.	-24.	-27.	5

CONFIG-URATION NUMBER	CONFIG-URATION NAME
1	BASELINE
2	SEPARATION ASSURANCE DEVICE WITH 100% AVIONICS CAPITAL COST ALLOCATION
3	SEPARATION ASSURANCE DEVICE WITH 50% AVIONICS CAPITAL COST ALLOCATION
4	AUTOMATIC DEPENDENT SURVEILLANCE WITH NETWORK HF DATA LINK AND VOICE
5	AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

TABLE 17-11

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH CAR CONFIGURATION RELATIVE TO BASELINE

(1979 DISCOUNTED US $ MILLIONS)

CONFIGURATION NUMBER	USERS			PROVIDERS			USERS + PROVIDERS			CONFIGURATION NAME
	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	CAPITAL COST	OPERATING COST	TOTAL COST	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
2	-24.	1.	-24.	0.	0.	0.	-24.	1.	-24.	SEP AS DEV, 100% AVIONICS COST
3	-12.	1.	-11.	0.	0.	0.	-12.	1.	-11.	SEP AS DEV, 50% AVIONICS COST
4	-20.	1.	-20.	3.	-34.	-32.	-18.	-34.	-51.	ADS WITH NETWORK HF
5	-24.	1.	-24.	-2.	-2.	-3.	-26.	-1.	-27.	ADS WITH SAT

Appendix A

HF DATA LINK AND VOICE SUPPORT DATA
(Prepared by FAA and SRI)

A.1 Working Group B HF Data Link Specification

Descriptions for the network HF data link and voice and simple network HF data link and voice systems were developed by Working Group B of the Committee to Review the Application of Satellite and Other Techniques to Civil Aviation. Summaries of these descriptions are provided in Sections A.5 and A.6 of this Appendix. The Network HF Data Link System is described in greater detail in Working Paper ARC 80/WP-17, Report of WGB to the ARC, Section 2, November 24, 1980. The simple network HF Data Link and Voice System is described in greater detail in Working Paper ARC 81/WP-2, Report of WGB to the ARC, Attachment 1, April 1981.

A.2 HF Ground Station Requirements and Frequency Allocations

For an ideal environment, Working Group B proposed the use of families (three data, one voice), with ten frequencies per family, one in each of the bands 2, 3, 4, 5, 6--21 MHz. Assuming that the Working Group B frequency allocation plan would be implemented, each station of the five shown would have 11 operating transmitters (ten data, one voice), except that two stations would have ten additional each, for a total of 75 transmitters. Including additional spares, the total number of transmitters required is about 85, of which about 70 are estimated to exist. Each station would need 40 receivers (for a total of 200) of which half are estimated to exist.

A.3 Master Ground Station Computer Requirements

Master ground stations must possess information on every flight either in or planning to enter the system. Furthermore, master stations must know where aircraft are so that they can determine when certain polling rates are to be used. In the case of dependent surveillance, records of which navigation system contains what data must be maintained for up to 220 aircraft or more. Data may have to be processed for about 70 aircraft every 30 seconds and for the remaining aircraft every 5 minutes to meet year 2005 requirements.

The master ground station must be able to handle input by controllers or other ATC personnel, including clearance changes, requests for special data from aircraft (i.e., request for heading data, more frequency position reports) and other information. Ground stations must also be able to distribute to ATC personnel position and other

information transmitted by aircraft. To be useful for ATC, all input/output must be conveniently formatted and processed. Alarms and other features must be built in the master station software to notify controllers of problems such as difficulties in communicating with particular aircraft.

The master station must balance loads and perform frequency management functions. Approximately 50 descriptors will be saved for each aircraft (including data for seven waypoints, each with latitude, longitude, time, and altitude) for recording flight plan related data, and another 50 will be saved for recording reported data and frequency management information such as assigned frequency. Some of the data might be stored on disc or other slow access memory while other portions must be sorted in active memory.

A rough estimate of the data required in such a system is made as follows: Aircraft data might require 100 x 300 = 30,000 2-byte words of description. Miscellaneous descriptive data such as FIR boundary data, track informaton, and weather data will at least double this for a total estimate of 120,000 bytes of storage. In addition, ten program modules of approximately 1,000 coded instructions, each written in a combination of high and low level languages, are budgeted to perform input/output, calculate conflicts, optimize HF channel use, etc. Industry estimates of costs for such codes (tested and debugged) ranges from $50 per line to $150 per line. A median figure of $100 per line has been used in this document.

Computers that might perform the required master station functions were costed based on available IBM equipment. Potential candidates range from the small scale Series 1 machines with 512 kilo-bytes and relatively slow speed to the 4340 with approximately 2-megabytes of storage. Various disc configuratons were also considered. Price estimates for this hardware ranged from about $100,000 to $600,000. A $250,000 value was chosen as being representative of hardware possessing desired functions.

A.4 HF Avionics Information

The HF data-link system as postulated by Working Group B presented a few design problems with respect to avionics hardware realization (and costing). In particular, the projected time sequence postulated by the Working Group implies an HF avionics system performance that is difficult to achieve. The following areas were of particular concern:

- Excessive retuning of transmit frequencies would wear out antenna couplers and would force a delay between the time a new frequency is chosen for transmit and actually used.
- The length of time (less than 0.2 seconds) during each uplink message is considered fairly short for locking onto an incoming signal and evaluating quality. AGC and other circuitry tends to require some time to reach steady state.

- Solid state HF couplers do not exist nor are they being developed. However, a coupler with finite L.C. elements which would be switched via vacuum relays is under development.

These areas of concern were treated as follows: First, it was assumed that frequency reevaluation by the transceiver logic would be carried out with couplers disconnected during the receive cycle. Secondly, it was assumed that the system would not need to reevaluate a new frequency very often (no more often than every 5 or 10 seconds; 5 seconds was subsequently selected by Working Group B). In addition, it was assumed that aircraft transmit frequencies would not be altered simply because one frequency propagated somewhat better than another frequency. As long as reasonable propagation existed on a frequency, the aircraft would remain on that frequency to avoid retuning. Hence, it was assumed in this costing exercise that existing couplers would be used in this HF system.

A survey, conducted by SRI, determined that HF receiver/transmitter units installed or being retrofit in most modern aircraft are Collins 628T units. Future aircraft are planned to carry this model or later ARINC 700 specification series transceivers. Collins felt these receiving/transmitting units adequate for the data link design.

A.5 Summary Description of the Network HF Data Link System

A.5.1 Introduction

This summary represents the latest stage in WGB's design of an advanced HF data link system, intended to meet the requirements of civil ATC for oceanic communications in the year 2005.

The communication requirements adopted by WGB for both HF and satellite data link systems are derived in Appendix C. These requirements are: 200 bps data rate in the ground-to-aircraft direction and 600 bps data rate in aircraft-to-ground direction. They are based on a position update of 2 reports per aircraft per minute for proximate aircraft and one report every 5 minutes for other aircraft.

The overall design philosophy adopted utilizes a linked network of ground stations for HF air-ground communications. Throughout each flight, each aircraft evaluates all frequency/path pairs available between the aircraft and the ground stations (all of which are interconnected), using its communication receiving equipment during intervals when it is not involved in data link communication. This evaluation is used to determine the best ground station through which to access each aircraft and the best frequency to be used.

The primary concern in the HF data link is with the long-term variability and propagation outages that afflict HF skywave operation. To provide system reliability in the presence of these effects, the design uses adaptive frequency and path selections that takes maximum advance of several network flexibilities:

a) Path Diversity
b) Band (Frequency) Diversity
c) Message Repetition (Time Diversity)

The methodology for path/band evaluation and adaptive selection is the heart of the overall HF data link system considered.

It is believed that an adaptive path/frequency selection system provides a basis for a highly reliable HF network operation in general. This represents a judgment widely held by the HF engineering community, including those represented on WGB. However, this judgment is inferred from widely scattered pieces of experimental data and a well defined body of experimental data to validate it does not exist at this time, and WGB recommended that a systematic, well designed data collection program be undertaken.

A.5.2 General System Description

It is widely recognized that an HF data system faces special problems because of rare but serious propagation disturbances which, it is believed, are both path and frequency dependent. Thus, the HF design provides a real-time procedure for choosing the optimum path-frequency pair for the air-ground link. Additionally, because of the short-term fading, the HF design should also provide timely message repeat capability consistent with the adopted reporting requirements. In the design adopted here, network operation will use regular ground-transmitted polling signals and aircraft replies to provide channel sounding functions.

The baseline HF system uses a data packet concept, based on 0.5 second time slots, each containing a ground-to-air poll segment and a subsequent message segment. Up to three independent uplink polling transmissions, from each of three separate ground stations, occur during each time slot: these are followed by independent message segments which may be used for either direction, but which are normally aircraft-to-ground replies. Each poll transmission from a station occurs on several frequencies simultaneously. Each set of frequencies constitutes a frequency "family" of which up to three are defined for use by the baseline HF data link system. Each family contains a frequency from each of 10 (R) bands distributed over the 2 to 22 MHz range, so that there are up to 10 frequencies per family. (This baseline approach assumes the use of more frequencies than are currently allotted to the North Atlantic (NAT) Organized Track System.)

To maximize air-ground path diversity, a fully interconnected network of five communications stations is assumed, ringing the North Atlantic. Three families of frequencies are assumed for this design, and each family is augmented, as compared with the currently assigned NAT A, B, C and D families to include 10 frequencies. Each family of ten frequencies is cycled through the total set of ground stations to establish the file of best ground stations for each aircraft at that time. Each aircraft will be preassigned to a specific frequency family and time slot, normally for the duration of a flight, but the assignments may be altered by a special uplink message, as a convenience in equalizing the network management load. A particular ground station will continue to transmit on all 10 of its frequencies as long as good communications are maintained.

In addition, it is expected that each aircraft will usually remain with a given ground station for relatively long intervals (10 minutes to 2 hours or more). Thus, the communications mode will tend to minimize the requirement on the avionics for frequency agility, and this also minimizes the rate of use of the aircraft high power antenna coupler for changes of aircraft transmit frequency.

Each ground station is envisaged to contain ten high-powered transmitters, one for each frequency in its assigned family, and will contain a separate receiver for each frequency assigned to the service and will monitor air-to-ground transmissions at all frequencies in all families (a total of 30 data receivers per station as the basic complement).

A.5.3 System Architecture

The ground network comprises five unattended HF radio stations, and two (hot-alternate) communications control centers, one on each side of the Atlantic, all fully interconnected by a full-duplex 2400 b/s data capability. Based on extension from present capabilities, an appropriate set of radio stations has been tentatively identified as:

- Shannon (or equivalent)
- Gander (or equivalent)
- Reykjavik (or equivalent)
- Santa Maria (or equivalent)
- San Juan (or equivalent)

The stations cover a wide geographic area, thereby providing a wide range of ionospheric reflection points to and from any particular aircraft, and both north-south and east-west paths. Reykjavik (or equivalent) is considered potentially important for aircraft tracks within the auroral zone, since trans-auroral propagation can sometimes be difficult.

Each band-diversity family will consist of 10 independent frequencies, one from each of the R bands. Although drawn from the ten R bands, each family is unique, and the same carrier frequency is never transmitted simultaneously from more than one ground station.

To provide the required combination of path diversity and band diversity, each of the five ground stations will be equipped with ten data transmitters and thirty data receivers (plus spares as required).

A separate family of frequencies is assumed for the residual voice communications that is stated to be a requirement. Since the aircraft will always have information regarding the available frequencies, each ground station needs to be equipped with only one frequency programmable transmitter for this purpose. It will, however, be equipped with the full complement of ten receivers for voice, in addition to the 30 data receivers discussed above.

The interrogate-response nature of the bulk of the required data flow led intuitively to a system design based on a time-slot format.

The basic scheduling and control interval is termed a time slot, and is illustrated in Figure A.1. Normally, an aircraft will transmit only in response to an uplink call, even when it is initiating routine requests. That is, it will wait until polled and use the aircraft message portion of the time slot to send a routine request. There will be provision of special time periods for time-critical aircraft initiation of messages (rapid-access or random-access periods).

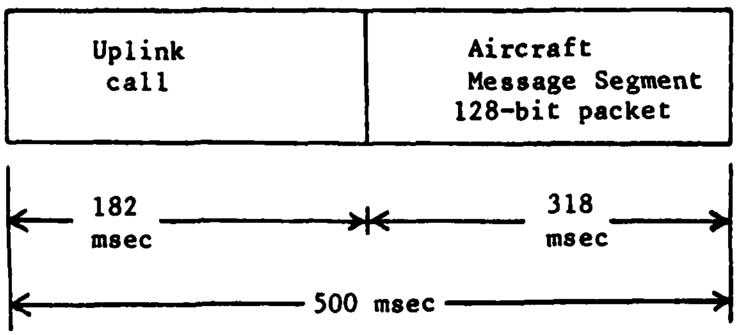


Figure A.1 TIME SLOT FORMAT

Occasional longer ground requests or replies will be continued over later time slots. The time slot chosen for this is 500 msec, divided into an uplink call segment of 182 msec and a message segment of 318 msec respectively. The data format within the time slot is discussed below.

The data flow requirements discussed in Appendix C indicate that the uplink calls can be accommodated well within 40 information bits. The dominating message requirement was observed to be the aircraft replies to "special report" queries, with lengths varying from 90 to 121 bits. Therefore, a packet size of 128 bits was assumed as the basis for an initial design. When multiple packets are needed for a message, a sequence of time slots will be allocated to that purpose (as access to their aircraft group is available), with packet sequence numbers assigned.

The proposed allocation of message time and number of bits is:

	guard interval	40 msec (20 bits)
Uplink call	Preamble & Header	62 msec (31 bits)
Segment	Uplink data	80 msec (40 bits)
Message	Preamble & Header	62 msec (31 bits)
segment	Message data	256 msec (128 bits)

The control centers' scheduling problem then reduces to that of selecting the ground station having the best path to a given aircraft, and fitting the 0.5 second exchange to that aircraft into a pattern containing exchanges with all other aircraft, with the constraint that the aircraft will be listening for a call in a known time slot once each 10 sec (a designated call epoch).

The control center will maintain a dynamic priority table of pending air-ground message exchanges. In general, the longer the time before an exchange is due, the lower will be its priority. The control process will continually examine the priority table and order as many exchanges as possible, up to 3, simultaneously. Three simultaneous exchanges are possible when they can be made on three different families from three different stations, i.e., a different family at each of three stations. At times, the highest priority exchanges can come from only 2 or even 1 station, the limitation being caused by poor propagation paths to the other stations. This will be the case when the number of aircraft having paths to only one particular station greatly exceeds the number of aircraft that can be served by other stations.

Since each time slot is 0.5 sec in duration, and up to 3 transmissions can be made at once, the system will achieve a 6-per-second effective polling rate at least part of the time.

Assuming that an effective polling rate of at least 4 per second rate can be maintained, 120 aircraft could be polled every 30 seconds (occupying 20 seconds of a 30 second epoch) and 400 additional could be polled once each 2 minutes if all were in the communications mode. This capability would exceed the projected traffic requirement. The uplink rate of 200 bps is achieved through the

4-6 uplink polls per second of 40 bits each, while the downlink rate of 600 bps is achieved through 4-6 downlink replies per second of 128 bits each.

Each ground station will have a separate receiver on each frequency of each family. A decoder on each receiver will detect any reply that is made to any uplink call, including replies to calls made from other ground stations. The signal quality of each reply will be quantified in some simple manner, and the reply at its signal quality will be passed to the control center. This information, along with path evaluations appended to position reports from the aircraft, will be used by the control center to optimize its choice of ground station for transmissions to each aircraft.

The data link assets available to the ground-based communication control centers (primary and alternate) consist of 5 ground stations, each of which has ten transmitters and 30 receivers. The transmission scheduling problem consists of assigning these assets, within the timing epoch constraints and the required maximum polling rate to some aircraft, to obtain adequate data flow to and from participating aircraft.

To simplify control, obtain rapid linkage, and provide the potential for anti-fading diversity (on the uplink), the ground control center will employ the frequency families as indivisible units. That is, any individual transmission to an aircraft will be radiated simultaneously on all of the individual frequencies of a family.

Aircraft will be assigned to a family for the duration of a flight, or until reassigned by a special uplink message. During the early phases of implementation of the data linked system, all aircraft can use a single family, but as the system adds users, the additional families (up to 3 total) must be employed. There will, therefore, be a natural means of transition from the present system to the automated one.

The aircraft control unit performs the only frequency selection in the system.* During the 9.5 out of every 10 seconds that an aircraft is not "at attention" for reception of a poll request, it will cycle its receiver through all frequencies in its family. Its detector will attempt to decode any uplink calls (directed to other aircraft) received during this time.

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*The ground stations transmit on all the frequencies of a family simultaneously, and therefore do not need to perform frequency selection. This approach eliminates the necessity for passing frequency selection information between ground and air.

The signals will be evaluated on the basis of the quality of the polling signals, possibly as determined from error coding parity checks incorporated into the uplink signal. The ground station transmitting each signal will be determined from the decoded message ID preamble. The control unit will maintain path/frequency quality evaluations.

The system provides, in addition to data, an ancillary ability to communicate air/ground on voice. To provide this capability one additional family is provided in the ultimate system for this purpose. The utilization of this channel is expected to be quite low. For voice communication, each ground station will include an additional ten receivers continually monitoring all frequencies in the voice family, but only one additional transmitter. The aircraft will have no additional equipment. Normally, voice communication will be initiated from either end by a data link request and acknowledgement, with the aircraft indicating the frequency band to be used, based on the data link frequency selection.

A.5.4 Network Management and Support

Each of the two control stations must be interconnected with each of the HF communications facilities, and with each other, using highly-reliable data communications circuits. Leased circuits, either land lines or satellite circuits, must be provided, with alternate message routing capability for improved reliability. At any given time one control station will be assigned primary responsibility. A backup data communications path will be provided for each communications facility through the secondary control station.

Twenty-four hundred bit per second duplex circuits will accommodate the estimated data interchange requirements between facilities. This assumes a bit rate of 850 b/s required for transfer of the downlinked information and the remaining capacity available for system management.

The "intelligence" required for network management has been centralized within the control stations. The primary control station will have responsibility for performing the following functions:

a) Establish and maintain the coordinated polling sequences for each of the five HF communications stations.

b) Assign a time slot to each aircraft.

c) Maintain files for all aircraft within the system and status of each.

d) Determine and activate or maintain the correct mode of operation for each aircraft, whether communication or recovery.

e) Communications message processing and message routing between communications stations.

A.5.5 Signal Design

To transmit 500 b/s information rate within a 3kHz channel allocation implies that the time-bandwidth product is available that can be used for signal design in order to achieve the following (non-independent) characteristics:

a) Minimum susceptibility to multipath degradation.
b) Significant diversity performance explicit in the signal design.*
c) Error-control coding.

Typical waveform formats known to the effective for use on fading channels include the following:

a) Multitone DPSK

Multiple, uniformly-spaced subcarriers each carry differentially phase-shift-keyed data. A typical design for HF utilizes 4-phase DPSK on each subcarrier at 75 baud (150 b/s), with subcarriers spaced by 110 Hz.

b) M-ary FSK

One out of M tones to represent log2 M bits of data. An 8-tone (octal, 3 bits/symbol) alphabet, has been examined in one study for FAA/TSC,** while at least one company has recently announced a 64-ary modem (6 bits/symbol).

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*Within a 0.5 second time slot, there may often be only small changes in the impulse response of the link. Therefore, the only in-band diversity available in the proposed design may be that resulting from multipath spread, which is manifested as a non-uniform transfer function within a 3kHz band. Thus, in-band frequency diversity may be available due to selectivity in the channel, or as multipath diversity resulting from use of a spread-spectrum waveform.

**Report No. FAA-EM-79-9, "Potential Use of High Frequency Data Transmission for Oceanic Air Traffic Control Improvement," Martin Nesenbergs, September 1979.

c) Spread - Spectrum

Some possibilities exist for using waveforms that occupy the full channel width (3kHz), with performance advantages deriving from the ability to resolve multipath (to order of 0.3 msec) for diversity. The spread-spectrum technique can use chirp waveforms or "direct sequence" phase-shift keying. As implemented with multiple correlators, such units would achieve in-band diversity by resolving independently fading paths within the overall multipath spread. A Canadian experimental system at 300 b/s has been reported which is almost ready to undergo experimental tests.

d) Adaptive Equalizers

Research is currently in progress on the design of adaptive equalizers to allow serial transmission of data at high rates over HF. Such systems consider, for example, use of four-phase PSK at rates of 1200 or 2400 baud. The corresponding symbol lengths are under 1 ms, and typical multipath spread will cause considerable smearing (intersymbol interference). The adaptive equalizers attempt to compensate for the smear. If successful, they will generally provide the error rate performance associated with coherent detection, and will contain diversity effectiveness derived from use of the multipath smeared components.

A.5.6 EQUIPMENT CONSIDERATION

Present state-of-art airborne HF receiver/transmitter (R/T) (as specified by the ARINC 719 characteristic) appear to be the most suitable for functioning in a computer-controlled air-ground data link network.

All aircraft will have dual-HF installations, each of which can be available for the data link air-ground communications. One airborne R/T unit will always be computer tuned to the optimum frequency. To provide redundancy, either HF R/T can be employed.

A data/frequency management unit must be added to each of the present aircraft HF communications installations and must perform the following instructions:

a) Identify the optimum frequency to be used for communicating with the optimum ground station in the network. Based on these data it will:

   i) Keep track of the optimum and suboptimum stations, and

   ii) Send data to the R/T to tune it to the optimum frequency.

b) During its attention slot, monitor the optimum frequency looking for its own assigned address. When own address is identified, respond with information requested in poll:

   i) Position report (including altitude): path report (optimum stations)

   ii) Meteorological data (when requested)

   iii) Other data or aircraft requests (e.g., altitude change, acknowledgements, etc.)

c) Decode and generate for display, the ground-to-air message generated by air traffic control, weather data, etc.

A voice communications request may be originated by the ground station. This will alert the flight crew to transfer one HF R/T to the optimum voice frequency. Tuning to this "best" voice frequency can be done automatically based on the known optimum data frequency. In the event the aircraft generates a voice communications request, it would either specify the optimum frequency in its request or simply start to use it.

A.5.7 Additional Studies Needed

The need for additional studies to confirm that path diversity, adaptive frequency selection and a well-designed signal will prevent extended outages in an HF data link system has been alluded to earlier in this report. As was noted, the fundamental assumption underlying the HF system design approach is that during rare, severe propagation disturbances, adequate path and channel capacity are available to support all aircraft reporting requirements, especially those associated with proximate aircraft. Data in support of this assumption are not available and an experiment is required to settle the issue. We also suggest additional studies:

1) To optimize the location of the HF ground stations, in particular any new station which is felt to be necessary to complete the network;

2) To evaluate more detailed signal design candidates approximate to the data link parameters, and

3) To validate by simulation the methodology for network operation, for typical channel characteristics.

A.6 Summary Description of a Simple Network HF Data Link

A.6.1 Introduction

This section presents a summary description of a system design concept for a simple HF data link network using the 6 NAT communications stations in a real-time network featuring single-site polling from either of two communications control stations located in Europe and North America. Included in this concept are several other system features: a single HF family (5 frequencies), polling interval to each aircraft of 5 minutes, and a less complex technique for frequency selection than that devised by WGB and summarized in the previous section.

The Group made no assumption about system reliability but instead addressed itself to the formulation of a consistent design which would meet the data transfer requirements for a 5 minute position report update interval, and which used the simplest possible equipment complement on the ground and in the aircraft. The following sections describe the system, tell how it works, and discuss several other topics related to operation in the current voice environment and to transition and growth.

A.6.2 Data Transfer Requirements

As a basis for the simple network HF datalink system design, the ATC data transfer requirements are assumed to be the same as described in Section C.3, Appendix C of this report, with the exception that there are no longer any "special position reports". Therefore, a total of 223 aircraft is assumed (peak load in 2005), with position reports every 5 minutes from each. In the network HF data link and voice system described in the previous section, a packet format was assumed with a 0.5 sec. time slot within which the first 200ms is used for an uplink poll and the next 300ms for a 128-bit "reply" packet (these times include guard times for variable propagation delays). The 128-bit packet size is adequate for each position report in the simplified network system, however, the revised data transfer requirements in terms of 128-bit packets, including both uplink and downlink messages, was reduced to 91 messages per minute.

The load of 91 messages per minute covers all ATC messages identified in the OASIS study; but, to allow for a 25% overhead, the message transfer rate requirement is increased to 114/minute. In the system concept envisioned here, only one poll/reply occurs per time slot over the entire system. Within this constraint, the 114 messages/minute fits well with the use of one 0.5 sec. time slot per poll/reply, just as in the fully adaptive system. Hence the basic packet and time slot structure described in the previous section can be carried over without change for data transfer in the present concept.

A.6.3 General Design Concept

The fundamental concept adopted is the use of a network of ground stations so that an aircraft transmission may be received at any of the communications stations of the network, and relayed to the communications control center. The network stations are assumed to be at the locations of the present HF communications stations, but it is assumed that new antennas and power amplifiers will be reqired at these stations both for technical reasons (requirements of antenna coverage and directivity, and frequency agility), and for operational reasons (requirement to maintain operation of current voice system during and after transition to a new data network). Each ground station also contains a receiver and data modem for each frequency in the family of 5 frequencies, as well as sufficient computation and communications control capability for network operation.

In its discussions, WGB was aware of the advantages of the additional diversity benefits conferred by use of the largest possible frequency family (11 frequencies under the current organization of the aeromobile spectrum), but has limited the system to a family of 5 frequencies for purposes of costing (the design of the system timing and protocols will accomodate a larger number of frequencies).

On the airborne side it is assumed that the aircraft will utilize the existing HF R/T units; the differences between the 618T and 628T equipments with respect to receive/transmit switching times and frequency tuning times are accomodated in the design. New equipments which will be required in the aircraft include the HF data modem and the HF data system management unit (MU). The aircraft equipment also contains a clock of the required stability and provisions for clock updating.

Each ground station transmits on only one frequency at any time. Ordinary message traffic is conducted for the first 4 out of 5 minutes of the polling cycle using one-half second polling exchanges like those of the fully adaptive network system. The fifth minute of each cycle is devoted to a systematic, sequential transmission of all the frequencies in the family by all the ground stations. Thus, station 1 transmits on frequency 1, followed by station 2 on frequency 1, and so on through station 6. Station 1 then transmits on frequency 2, followed by station 2, and so on. The transmission sequence is synchronized in the aircraft receiver and the best frequencies are evaluated and maintained in an aircraft file. If the quality of the last polling frequency is adequate, the aircraft can identify the best frequencies as part of its next poll response and remain tuned to this frequency indefinitely. If the quality of the last polling frequency is not adequate, the aircraft uses one of the random access slots provided in the timing sequence to tell the ground that it wishes to send a channel evaluation message (or other data).

To provide air-ground path diversity, a network of 6 communications stations is assumed, 3 on each side of the Atlantic. Each 3-station group is connected to a communications control center ("star" network) and the two star-networks are connected by a reliable trans-Atlantic data link. Unlike the network of the fully adaptive system, connectivity for this case has been limited in order to reduce recurring point-to-point communications costs. The two communications centers would exchange information about their respective network stations, but, if this link were broken, the two sides of the ocean would control aircraft independently. Procedural means would be used to transfer aircraft in transit from one communications center to the other.

The general concept is for a particular communications station to communicate with a given aircraft on a single frequency until the aircraft or the ground station determines that the SNR or some other quality measure is marginal, at which time the aircraft listens to and evaluates the sounding transmissions to select a better frequency and/or ground station. This approach implies that the system will function using existing aircraft antenna couplers since the aircraft will only occasionally retune for transmission.

The most likely candidates for a near-term HF modem suitable for use in the simple network HF system implementation are M-ary Frequency-Shift Keying (FSK) and Multitone Differential Phase-Shift Keying (DPSK). Either technique would likely include rate-1/2 coding to improve error-rate performance on the fading HF channel. For a data (information transfer) rate exceeding about 300 b/s, the higher packing density available in a fixed bandwidth via multitone DPSK is a strong argument for use of the DPSK technique.

A third candidate of less traditional type is a spread-spectrum modem within the same nominal 3 KHz. This is the subject of recent and ongoing development, and appears to be of the same order of modem implementation complexity as the traditional techniques. The spread-spectrum modem achieves a form of multipath diversity that may allow use of higher-rate coding or no coding at all. It appears limited to transmitted data rates of about 300 b/s, possibly as high as 600 b/s.

A.6.4 Summary Description of the ARINC HF Data Link Proposal

In submission to Working Group B and the ARC, (ARC 81/WP-7, "A possible approach to the early introduction...of air-ground data communications...", May 1981), Aeronautical Radio, Inc., (ARINC) outlined an HF Data Link System "Strawman" that they are actively considering as a commercial venture for airline operators equipped with VHF ACARS. The design philosophy used by ARINC was directed at an early implementation of an HF data link capability, with

consideration for future growth, rather than the ATC data transfer requirements for the year 2005 upon which all other WGB data link proposals were based. This section summarizes salient features of the ARINC Strawman and comments by WGB.

The significant characteristics of the ARINC Strawman are as follows:

1) The normal communications mode is viewed as "demand access" with aircraft freely originating messages as needed. In addition to ground interrogations for position reports or other information. Messages occur asynchronously, initiated after first observing that the channel appears free, and have durations as needed for the message content. Contention difficulties are resolved by retries, and a backup polling mode discipline is envisioned to be used if the demands for the channel become too great. The backup polling uses query/response, but does not involve a regular time-slot structure as in the simplified network HF data link system of WGB.

2) A single transmission on a single frequency may occur from any ground station or aircraft at any time; two or more ground stations or aircraft may transmit simultaneously (to different aircraft) on different frequencies. Ground transmissions may be replies to an aircraft message, ground-initiated messages or queries, or a "squitter" call. In order to allow aircraft to maintain an assessment of the quality of alternate frequencies allocated to the system, the ground transmits a squitter, which is a non-addressed message ("All Call") on a frequency not otherwise radiated within a given time (one to two minutes). Aircraft transmissions will include the address of the ground station to which they connect.

3) For North Atlantic operation, three stations on each side of the ocean are tied to a communications control center (one network on each side of the ocean), with a single family of frequencies per network. Alternately, a single frequency family is time-shared between the two networks.

4) The two communications control centers are tied together by a data circuit. Aircraft which cannot be heard by their primary station but which can be heard from other stations will communicate via these other stations, using the data circuit for coordination.

5) Each station has a set of ground receivers covering every frequency in use (on both sides of the ocean).

6) In the normal mode, aircraft listen on their selected frequency for uplink transmissions. All uplink transmissions contain station I.D. The aircraft demodulate each transmission and estimate its quality (via error control decoding). A timer is reset each time a valid (adequate quality) uplink transmission is received (including squitter calls). After a time-out period of no successful receipts, the aircraft enters a search mode, stepping over its other frequencies to find one that is acceptable.

Some doubt was felt by WGB that the demand mode could service the system mangement and traffic load in any case, and that the control mechanism for switchover to a poll mode would be trouble-free. WGB also questioned whether system analysis or simulation would support ARINC's assumption that the demand-access mode will give acceptable operation at a data-transfer rate of 150 b/sec (300 b/sec transmitted symbol rate using rate - 1/2 coding), and whether the data tranfer rate must be held that low in order to achieve low modem/codec costs and early availability. (Note: the exact data rate and any coding has not been decided.)

In the absence of sizing and costing information on the ARINC Strawman, WGB noted that its proposal for a simple network HF data link system and the ARINC Strawman are substantially similar in the configuration of the ground communications stations, the ground network arrangements and the avionics configuration. In addition, all large cost elements for the two systems appear to be identical. These new ground station installations and their associated costs arise because of the need for continuing and compatible operation of the existing voice system as the data link network is implemented. Thus very substantial new costs will be incurred for either system for communications station implementation and recurring ground-ground data transmission costs.

Approximately once each minute, but not on a fixed schedule, each ground station will make a random access poll on each frequency that it is currently using for traffic. If the site receives a reply, it will respond to the requesting aircraft, add it to the poll table, and repeat the random access call. This will allow aircraft to enter the system within 1 minute if they are given a frequency and station, as by VHF data link or SSB voice, or other means, at the beginning of a flight.

As has been described in earlier sections, the data link concept described here assumes the use of new ground station equipment (antennas, transmitters, receivers, processors, etc.) since interference with the existing voice system is not permitted. On the aircraft, the R/T unit, antenna and coupler are assumed shared between voice and data services but a new HF data modem and new management unit and peripherals are assumed.

APPENDIX B
SATELLITE SUPPORT INFORMATION
(Prepared by FAA and SRI)

B.1 Working Group B Satellite System Description

Specifications of the satellite data link and voice system, including link budgets and supporting information, was developed by Working Group B of the Aviation Review Committee. The satellite system concept is described in ARC 80/WP-17 (Report of WGB to the ARC, Section 3, November 24, 1980). A brief summary of this description is included below in Section B.3, as indicated by the indented text.

B.2 Ground Station Costs

Satellite ground station technology is highly developed. At the suggestion of Intelsat, Professor Bruce Lusignian of Stanford University provided data on the costs of such a facility based on recent experience with the development of several such stations.

Calculations of required computer processor support equipment showed that a Satellite Data Link and Voice System would need so many of the functions associated with the Network HF Data Link and Voice system that virtually the same components could be used for cost estimation purposes. Although a satellite master ground station would not need a frequency management software module, it would need a module for dealing with Doppler shifts.

Satellite avionics estimates were difficult to make within the allowable time limits. The elements involved, such as L-Band power amplifiers and VHF antennas, do not have useful analogs in the aviation industry. One important factor is the need for relatively high power L-band amplification to meet a voice requirement. The Working Group B recommendation of placing the amplifier in the avionics rack doubles the amount of power required because of cable losses. Placement of the amplifier near the antenna appears to be reasonable and possible, at least for widebody aircraft. Hence, this type of power amplifier installation was assumed.

This consideration and others (related to the use of VHF antennas) prompted us to call Mr. Robert Sutton of Boeing regarding possible costs associated with airframe modifications. Discussions with Boeing indicated that the cost of a modification to an aircraft type to account for structural analysis and certification may range from $50,000 per aircraft type to $500,000. The lower end would correspond to a one-time cost associated with cutting metal and doubling (i.e., reinforcing a

small area of sheet metal), but not involving bulkheads and stringers. Bulkheads are spaced from 19-20 inches apart and stringers have about 7 inches between them. Making bulkhead modifications requires extensive analysis.

L-band appears to offer less technical uncertainty with respect to performance than VHF: (1) Comparable aircraft L-Band antennas are much smaller and easier to install than VHF antennas (with possible associated cost impacts); (2) it is more difficult to obtain aircraft antenna associated discrimination against sea reflected multipath at VHF; (3) the characteristics of sea reflected multipath at VHF may significantly impact the level of performance (since the VHF wavelength is nearly an order of magnitude longer than the L-Band wavelength, the multipath at VHF may have a significant coherent component which would cause periodic fading and enhancement of the direct path signal); (4) VHF is subject to much deeper fades due to scintillation; (5) L-Band is a cleaner spectrum from the potential ground based interference standpoint; and (6) much more experimentation has been carried out at L-Band (in particular the international programs that used the U.S. National Aeronautics and Space Administration's Applications Technology Satellites 5 and 6, i.e., ATS-5 and ATS-6), and thus the performance characteristics of L-Band under various conditions and with various modulation techniques are known. In addition, the VHF frequency allocations would not readily provide for the frequency needs associated with a growing satellite system. A complete cost comparison would require further analysis.

At an informal meeting of several Working Group B members, Ford Aerospace indicated that VHF antennas on spacecraft would probably present problems with respect to sharing a satellite platform. This fact, coupled with the technical uncertainties of VHF, led SRI to analyze the costs of an L-Band system.

B.3 Summary Satellite System Description

B.3.1 Introduction

In order that the HF and satellite-based communications improvement options may be properly compared, the Working Group adopted a uniform set of communications requirements for ATC up to the year 2005. These requirements are set forth in Section C.3 of Appendix C to this report. The basic data rate for the most stringent requirements is 200 bps uplink and 600 bps downlink (position update rate assumptions of two reports/min for proximate aircraft and one report every 5 minutes for other aircraft). It is noted that these requirements do not, however, address the needs of airline company communications or other services. (The uplink data rates of 160 bps and 200 bps corresponding to 1 min/poll and 0.5 min/poll for proximate aircraft used in the

WGB report are slightly higher than the rates of 130 bps and 170 bps presented in Appendix C due to a refinement of these requirements after the satellite system analyses were completed. The small differences did not appear to warrant a re-working of the system description at that time.)

The approach pursued by WGB was believed to be a conservative and hopefully an economical one while at the same time leaving sufficient latitude for growth. The system concept centres on a satellite transponder service from geosynchronous positions that focus primarily on the North Atlantic region. Both VHF and L-Bank satellite-to-aircraft links were considered in the satellite system designs; however, a satellite transponder would use either L-Band of VHF frequencies but not both. The baseline design concept calls for providing a level of data transmission, which will shortly be described, in addition to a voice capability that would be constrainted to have a low utilization, e.g., for unusual communications circumstances. Section B.5 assesses the impact on the system if this voice requirement were eliminated.

B.3.2 System Description

The general characteristics of the system includes various operating parameters and constraints on specific segments detailed below:

1) Coverage

   The transponder would be located in geosynchronous orbit above the Atlantic Ocean to provide North Atlantic and Caribbean Ocean area coverage approximately as shown in the accompanying map. No performance degradation is allowed during satellite eclipse periods.

2) Frequencies

(i)	Ground-to-satellite:	5.0 GHz to 5.125 GHz
(ii)	Satellite-to-ground:	5.125 GHz to 5.25 GHz
(iii)	Satellite-to-aircraft:	1.545 GHz to 1.559 GHz or 118 MHz to 137 MHz
(iv)	Aircraft-to-satellite:	1.6465 GHz to 1.660 GHz or 118 MHz to 137 MHz

3) Functional Characteristics

(i)	L-Band - to - C-Band transponder or VHF - to - C-Band transponder	A/c-to-ground com.
(ii)	C-Band - to - L-Band transponder or C-Band - to - VHF transponder	Ground-to-A/C com.
(iii)	C-Band - to - C-Band transponder:	System Management (Ground-to-ground)

The accompanying simplified functional block diagram illustrates the required transponder information paths in the case of L-Band.

B.3.2.1 Avionics Design/Aircraft Antenna System

For the satellite system design a nominal antenna gains of +1dB was assumed. This theoretical figure is the gain of the aircraft antenna at elevation angles greater than 10^{o} over 90 to 95 percent of the azimuthal coverage. Holes in coverage or loss of signal due to major roll attitudes of the aircraft are dealt with operationally, i.e., re-transmissions if the system margin is inadequate.

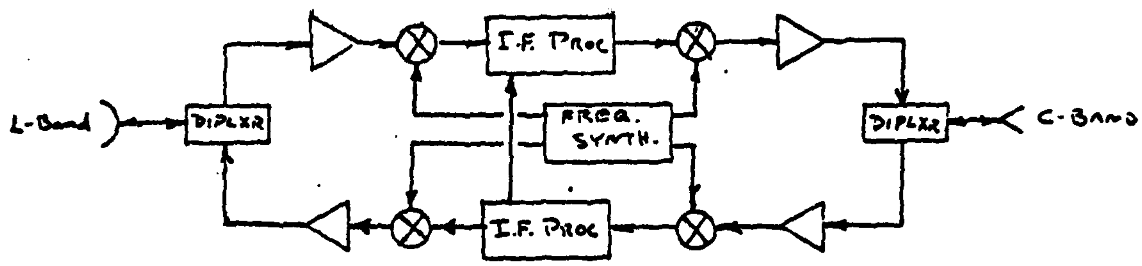
Due to the critical accessibility for maintenance only low noise preamplifiers (300^{o}K noise temp. assumed) seem to be acceptable for mounting near the antenna. Very high antenna system MTBUR (Mean Time Between Unscheduled Removals) is a stringent requirement. (10,000 hrs.) Transmitter cable losses of up to 3 to 4dB should be allowed.

The interface requirements to other avionics equipment onboard the aircraft should be limited, wherever possible to those parameters which are easily available in digital form from only a few ARINC 429 buses. Buffering, where required, must be done within the transceiver.

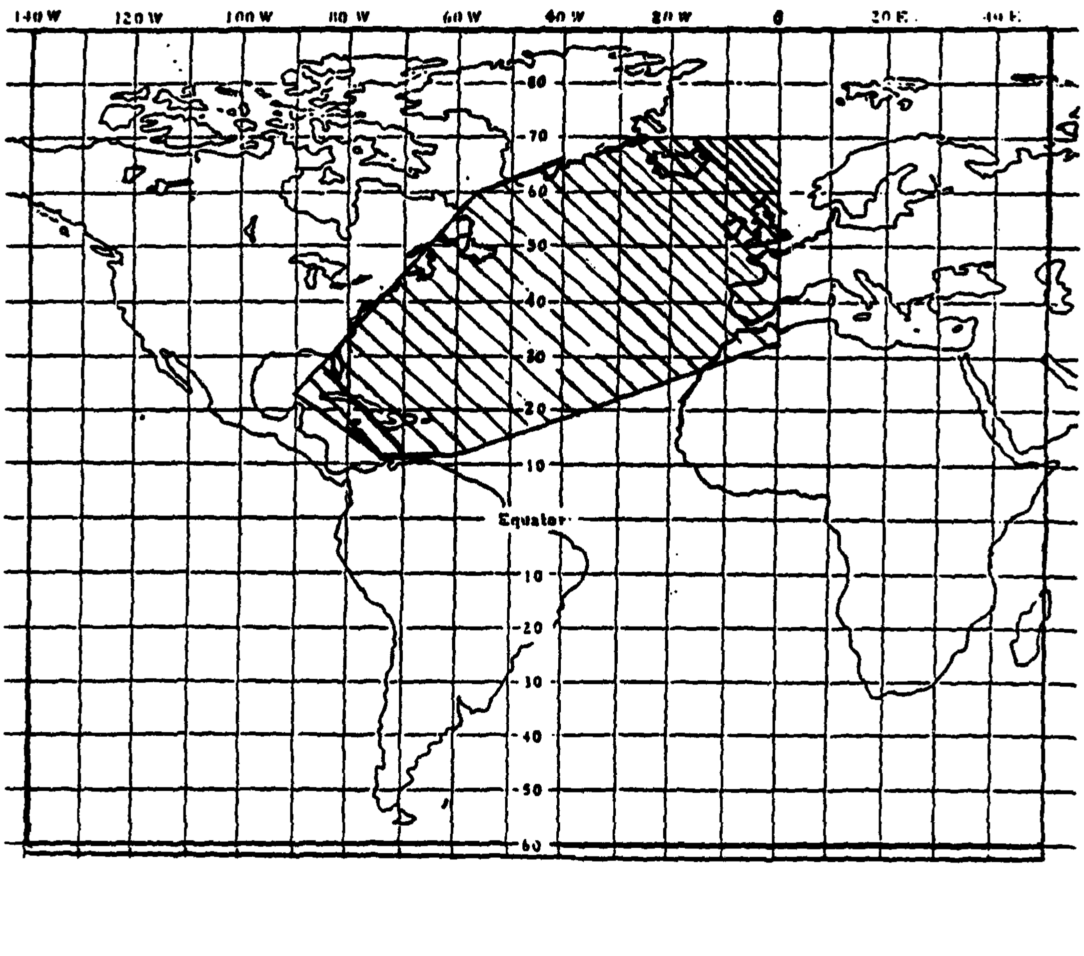
B.3.2.2 Space Segment

The nature of the space segment will be influenced to a large extent by the type of sharing arrangements obtained. The design philosophy adopted was to assume that an aeronautical satellite transponder shares a spacecraft bus with another payload. Thus, the transponder derives primary power and associated service from a common bus. Both L-band and VHF versions would require a significant amount of antenna space. Nevertheless, the L-band antenna would be more compact, in

SATELLITE FUNCTIONAL BLOCK DIAGRAM



COVERAGE SERVICE AREA



spite of the fact that its coverage is limited to the NAT and less constraining to other antenna systems. A solid state implementation is envisaged throughout the transponder design. The C-band antenna is envisaged as an earth-coverage horn.

The bandwidth of the transponder would be relatively narrow, since it would carry at most two narrow-band signals (low-speed data and voice) in the ground-to-air direction and possibly several narrow-band, low-speed data channels in the other direction.

B.3.2.3 Ground Terminal

The approach used to define the Ground Terminal is to keep the antenna size as small as practicable without affecting satellite cost appreciably. If the antenna size is sufficiently small, say of the order of 3m to 5m, then the antenna can be a non-tracking type or, at most resort to the simpler tracking schemes such as step or program track. A 3m dish antenna has a half-power beamwidth of slightly more than 1° at 5 GHz and a peak gain of about 44dB. It is assumed to provide at least 41dB gain. A system noise temperature of 200°K is assumed. The resulting G/T for the ground terminal is +18dB$^\circ$K. In addition to the antenna and low noise receivers, the ground terminal will include the necessary amplifiers, I.F. processors, modems and interface equipment.

B.3.2.4 System Operation

1) Ground-to-air channels

There is assumed to be one ground-to-air data channel and one ground-to-air voice channel. The data channel will continuously send information at 200 bps* to the entire coverage region. Each aircraft tunes to this beacon-like signal well in advance of entering the service area and essentially stays tuned to it with only brief interruption such as when the aircraft transmits a burst reply or when the aircraft maneuvers in such a way as to cause blocking of the line-of-sight to the satellite. In these cases the avionics must re-acquire the signal by initiating a search at that frequency where drop-out occurred.

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*WGB developed three concepts of 100 bps, 160 bps and 200 bps ground-to-air data rate configurations (and associated air-to-ground rates of 300 bps, 400 bps or 600 bps) corresponding to position update rates for proximate aircraft of one per 2 minutes, 1 minute, and 30 seconds respectively. Only the 200 bps case is retained for the sake of brevity in this summary.

The forward voice channel is designed for low utilization. Its utilization may be expected to be well below 0.2. This channel is broadcast to the entire coverage region. Channel selection will probably be manual with a data-linked indicator (like SELCAL) if voice communication is to be initiated by the ground.

2) Air-to-Ground Channels

The operational concept allows for either single or multiple air-to-ground data channels. The volume of data has been estimated to be about 600 bps. In addition, a 100 bps overhead was assumed to account for reply preambles necessary for signal acquisition as well as for the inevitable guardtimes that are necessary to prevent simultaneous arrival of different transmissions within the same channel at the satellite.

The voice return channel, like its forward counterpart, is expected to have a low utilization. In order to use satellite power most efficiently, it is likely that his voice channel can only be received on the ground and not by other aircraft. Since the forward and return pair of channels are operated half-duplex, i.e., on different frequencies but not simultaneously, it is possible to re-broadcast each aircraft originated voice message to serve as a busy indication to all other users. However, this could be wasteful of satellite primary power. The access to this voice channel is controlled from the ground via requests issued by aircraft on either the periodic data polls or through a separate random rapid access channel. Clearances to use the voice channel will be determined on the ground, on a priority basis if necessary, and transmitted to the requesting aircraft.

3) Channel Access

All routine data communication is performed through periodic polls of all aircraft in the system. These polls are conducted from a sequence list maintained by computers in both ground stations. The ordering is dynamically maintained to permit up to two polls per aircraft per minute for some aircraft.

A random access channel is a frequency or time slot of low utilization that may be used by aircraft to initiate a message transaction with the ground prior to a ground-initiated poll. Aircraft that are on less frequent polling cycles or random "pop-ups" would be the most

likely users of such a channel. Aircraft leaving the control system would be handed over to the appropriate adjacent enroute control sectors in a manner that is functionally equivalent to the current practice.

B.3.2.5 General Signal Characteristics

In the previous section it was pointed out that forward transmissions are essentially continuous and broadcast in nature whereas return transmissions are short bursts in reply to polling requests. Embedded in the forward signal stream are specific aircraft addresses followed by instructions and/or requests for specific kinds of information.

The return communications sequence is inherently more complicated than the forward segment. This is due to the fact that return transmissions are bursts originating at the aircraft from widely dispersed geographical locations and with varying doppler offsets. Furthermore, practical economic factors limit the avionics oscillator precision and the peak transmitter power.

To some extent, such equipment limitations can be compensated through the use of more sophisticated ground receiving equipment. In particular, it is reasonable to expect that the ground equipment would retain the last known frequency offset for each aircraft (this includes the aircraft transmission doppler shift) and, to some extent, predict its value at the time of the next anticipated reception.

Another very important consideraton in the signal design for both forward and return signals is the consideration of multipath. The extent of this problem will depend largely on the aircraft antenna geometry. Signals that are robust to this environment must be considered.

B.4 System Performance

B.4.1 Performance Requirements

General performance requirements are as follows:

a) The received data messages should show a bit error rate of 10^{-5} or better.

b) The voice messages to be received should have the same level of intelligibility as the one achieved with current overland VHF air/ground communication channels.

B.4.2 System Parameters and Assumptions

The following parameters are believed to be conservative estimates of what can be reasonably achieved, and assumptions believed to be acceptable for the purpose of satellite link designs.

a) The aircraft receiver noise temperature (including antenna contribution) is of the order of 1300°K at VHF and 500° at L-Band.

b) The aircraft antenna gain is assumed to be -1 dB at VHF and +1 dB at L-Band for elevation angles above 10°. A margin of 1.5 dB at VHF and 3 dB at L-Band is allowed for cable and miscellaneous losses.

c) The spacecraft receiver noise temperature is of the order of 2000° K at VHF, 1000° at L-Band and 2000° at C-Band.

d) The spacecraft antenna gain is assumed to be 120 dB at VHF, 20 dB at L-Band and 17 dB at C-Band. A margin of 1.5 dB is allowed for feeder and diplexer losses. An allocation of 0.5 dB is allowed for miscellaneous losses at C-Band.

e) The ground station receiver noise temperature is of the order of 200° K (B-Band).

f) The ground station antenna gain is assumed to be 41 dB (C-Band). A margin of about 2 dB is allowed for cable and miscellaneous losses.

g) The spacecraft transponder is assumed to be of the saturated type.

h) The spacecraft power amplifier DC to RF conversion efficiency is about 50% at VHF, and 28% at L-Band.

i) The C-Band Carrier to Noise density ratio requirement has been arbitrarily chosen to be 15 dB above the ones for aircraft to spacecraft and spacecraft to aircraft links. This level allows the separation of each path into two distinct links with C-Band noise degradation at a negligible level.

j) The acceptable link margins required to compensate for path anomalies encountered by various types of satellite links are assumed to be as follows:

2 dB for C-Band links
5 dB for L-Band links
11 dB for VHF links.

B.4.3 Link Analysis

The required C/No for the aircraft/satellite data communication links are based on approximately 12 dB signal to noise ratio in a bandwidth equivalent to the information data rate. This signal level is close to the minimum required for candidate modulation schemes, (allowing for implementation losses) but should be adequate to provide the necessary error rates in a multipath environment if a suitable coding scheme is employed.

The required C/No for voice communication links is assumed to be 43 dBHz.

A summary of the communication links showing the required power for the satellite and aircraft transmitters for both VHF and L-Band and for voice and data is shown below:

	Aircraft Transmitter RF Power (Watts)		Satellite Transmitter DC Power (Watts)	
Communication Load Option	VHF */**	L-Band */**	VHF	L-Band
30 sec polling interval for close proximity aircraft	11/45	12/63	14	20
Voice Communication Channel	71	100	89	127

* This refers to the multiple return channel implementation at same data rate as the forward link.

** This refers to the single return channel implementation.

B.5 Impact of Removing Voice Capability

The vice channel requirement can have a significant impact on the satellite system implementation. It affects primarily the aircraft-to-satellite and satellite-to-aircraft links.

In these communications links, a data rate of 200 bps to 700 bps has been identified as the ATC requirement. The power levels needed to support adequate data transmissions at these rates is considerably less than that required for a conventional voice transmission. In order to provide acceptable voice communications, either the transmitted power levels must be increased or one must resort to more complex voice processing equipment to provide the voice service at lower power. The current state of the art provides low-bit-rate voice communications over channels that will support as little as 1 kbps.

The approach taken in this satellite system characterization is to size both avionics and satellite transponder to provide adequate power levels for conventional voice communications. The projected size of such power amplifiers is in the vicinity of 100 w continuous RF output power. If the voice requirement were removed, the required peak power output is expected to drop to about 25 watts. Furthermore, since the data transmission is bursty and on a low duty factor, the average RF power output is of the order of 1 watt or less.

The impact on the satellite transponder on the satellite transponder cost of removing the voice channel may also be significant, though perhaps not to the same extent. In the case of the satellite transponder, the peak and average data transmission power requirement is essentially constant. Nevertheless, a greater EIRP requirement in the satellite will likely increase the cost of service either through higher primary power requirements of larger antenna and hence a more complex feed/receiving system in the satellite.

The cost impact of removing the voice channel is contained in the appropriate Cost Factor Section of this report.

LINK : GROUND TO SPACECRAFT C BAND

CASE : 30 sec. Minimum Polling Interval

Types of channels	200 BPS	700 BPS
Required C/No	50 dbHz	56 dBHz
- G/T	16 dB/°K	16 dB/°K
- Lp	199 dB	199 dB
K	-229 dBw/Hz-°K	-229 Hz-°K
Margin	2 dB	2 dB
Required EIRP	38 dBw	44 dBw
Cable and Miscellaneous Losses	2 dB	2 dB
G_t	41 dB	41 dB
Required RF power	-1 dBw (0.8 w)	5 dBw (3.2 w)

LINK : SPACECRAFT TO GROUND - C BAND

CASE : 30 sec. Minimum Polling Interval

Types of Channels	200 BPS	700 BPS
Required C/No	50 dBHz	56 dBHz
-G/T	-18 dB/°K	-18 dB/°K
-Lp	199 dB	199 dB
K	-229 dBw/Hz-°K	-229 dBw/Hz-°K
Margin	2 dB	2 dB
Required EIRP	4 dBw	10 dBw
Miscellaneous losses	0.5 dB	-6.5 dBw
G_t	17 dB	17 dB
Required RF power	-12.5 dBw (0.06 w)	-6.5 dBw (0.2 w)

LINK: SPACECRAFT - AIRCRAFT L BAND
CASE: 30 sec Minimum Polling Interval

Types of Channels	200 BPS	
Required C/No	35 dBHz	
- G/T	26 dB/°K	
- Lp	189 dB	
K	-229 dBw/Hz°-K	
Margin	5 dB	
Required EIRP	26 dBw	
Feeder and diplexer losses	1.5 dB	
G_t	20 dB	
Required RF power	7.5 dBw (5.6 w)	
Required DC power (28 % efficiency)	13 dBw (20 w)	

LINK: AIRCRAFT TO SPACECRAFT - L BAND
CASE: 30 sec Minimum Polling Interval

Types of Channels	200 BPS	700 BPS
Required C/No	35 dBHz	41 dBHz
-G/T	10 dB/°K	10 dB/°K
-Lp	189 dB	189 dB
K	-229 dBw/Hz-°K	-229 dBw/Hz-°K
Margin	5 dB	5 dB
Required EIRP	10 dBw	16 dBw
Cable and miscellaneous losses	3 dB	3 dB
G_t	1 dB	1 dB
Required RF power	12 dBw (16 w)	18 dBw (63 w)

LINK : AIRCRAFT TO SPACECRAFT
CASE : Voice Channel

Types of Channel (Options)	A/C To S/C L-Band	A/C To S/C VHF-Band
Required C/No	43 dBHz	43 dBHz
-G/T	10 dB/°K	23 dB/°K
-Lp	189 dB	168 dB
K	-229 dBw/Hz-°K	-229 dBw/Hz-°K
Margin	5 dB	11 dB
Required EIRP	18 dBw	16 dBw
Cable and miscalleneous losses	3 dB	1.5 dB
G_t	1 dB	-1 dB
Required RF power	20 dBw (100 w)	18.5 dBw (71 w)

LINK : SPACECRAFT TO AIRCRAFT L & VHF
CASE : Voice Channel

Types of Channels (Options)	S/C To A/C L - Band	S/C To A/C VHF-Band
Required C/No	43 dBHz	43 dBHz
-G/T	26 dB/°K	32 dB/°K
-Lp	189 dB	168 dB
K	-229 dBw/hZ-°K	-229 dBw/Hz-°K
Margin	5 dB	11 dB
Required EIRP	34 dBw	25 dBw
Feeder and diplexer losses	1.5 dB	1.5 dB
G_t	20 dB	10 dB
Required RF power	15.5 dBw (35.5 w)	16.5 dBw (44.6 w)
Required DC power	21 dBw (127 w) (28% efficiency)	19.5 dBw (89 w) (50% efficiency)

Appendix C
SYSTEM REQUIREMENTS
(Prepared by FAA and SRI)

C.1 Introduction

This section presents a derivation of various operating requirements that might be associated with technological improvements. Requirements are developed for dependent surveillance function and an airborne separation assurance device. Section C.2 describes dependent surveillance and Section C.3 addresses communications requirements. In C.4 alarm rate estimates for separation assurance devices and surveillance are developed.

C.2 Dependent Surveillance

This section develops relationships between lateral separation minima (and related operating parameters) and the communicatins capabilities of an automated digital communications link capable of supporting a dependent surveillance function. A parametric model of a dependent surveillance process is developed and solved for the parameters that appear to give acceptable performance. The development presented here is an outgrowth of results first presented in ref. 1 and subsequently improved.

The dependent surveillance function itself has been developed and examined to the extent believed necessary to determine if the position update rates postulated at the 4th Committee Meeting were reasonable and to determine if the function appeared to be sufficiently practicable to merit further examination. Therefore, the following development and analysis of the surveillance function should not be viewed as exhaustive. However, careful consideration has been given to selecting reasonable parameter values, such as controller function times, off-track aircraft deviations, and corrective maneuvers.

C.2.1 The Generic Surveillance Function

The use of surveillance to improve flight safety by decreasing the incidence of collision risk involves two primary parameters: (1) the total position location error of the entire surveillance system due to such factors as the sensor, signal propagation, data processing, and data display, which will hereafter be referred to as the maximum surveillance (MSE) error; and (2) an absolute minimum allowable spacing between pairs of aircraft, which will hereafter be referred to as the minimum aircraft-to-aircraft spacing (MAS). The MAS is intended to

provide a substantial margin of collision risk safety in those rare circumstances where some system lapse has occurred and the MAS is compromised. The sum of the MSE and the MAS equals the surveillance separation (SS), which is the minimum indicated target spacing (on the display or from another position location data source) allowed such that the MAS is not compromised.

C.2.2 Surveillance Correction Model

Figure C-1 presents a basic outline of cross-track incremental distance allocations for correction of navigation error using surveillance. The figure shows an aircraft deviating from its track, receiving corrective information, and returning to its track. The parameters are defined as follows:

D1 = Cross-track distance travelled by the aircraft during a surveillance polling period. This could account for a deviation from track beginning after a surveillance poll or after the aircraft enters the polling table (assumed to be the last entry in the table).

D2 = Cross-track distance traveled during the controller error recognition and correction initiation time plus controller-to-pilot message transmission time plus pilot action initiation time.

D3 = Cross-track distance travelled by the aircraft in a coordinated turn towards its track (i.e., the cross track distance away from the track traveled after a pilot initiates a corrective turn).

Let t = Time between surveillance polls (in minutes), associated with
s = Speed of aircraft (N miles per minute)
T1 = Time associated with D1.
T2 = Time associated with D2.
ϕ = Assumed bank angle of aircraft in coordinated turn.

The amount of aircraft deviation associated with D3 can be be determined from basic geometry and the physics associated with the coordinated turn. Figure C-2 shows the geometry and the simple force balance physics.

From the figures:

$$F_c = \frac{ms^2}{r} = L\sin\phi$$

$$\text{and } Mg = L\cos\phi$$

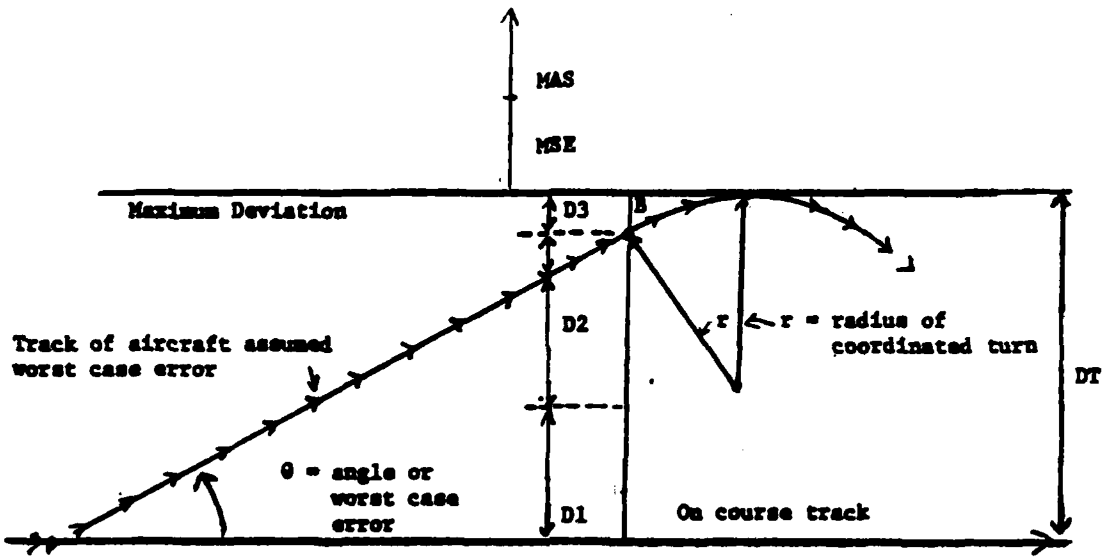


Figure C-1: Model of Surveillance Correction Process

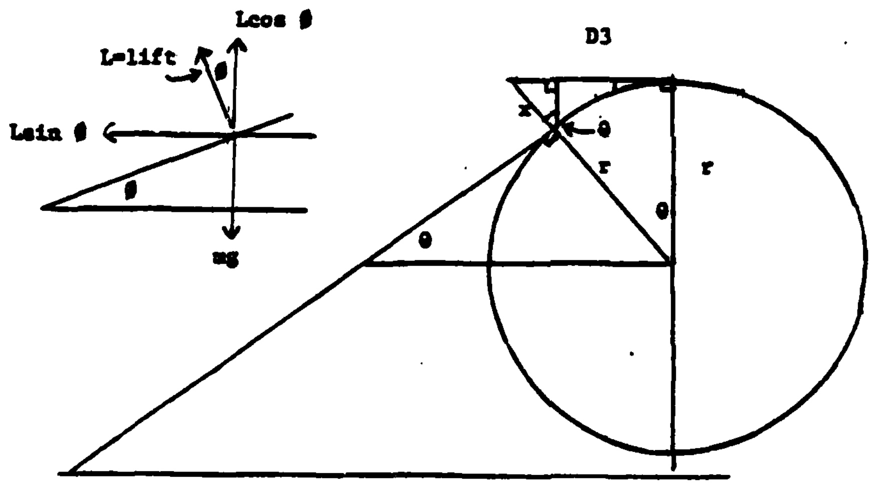


Figure C-2: Geometry of Coordinated Turn

Solving for L in both equations and equating the results gives

$$\frac{ms^2}{r\sin\phi} = \frac{mg}{\cos\phi}$$

which can be solved for r to give

$$r = s^2/g\tan\phi$$

Also, from geometry

$$\cos\theta = r/(r+x) \rightarrow x = r/\cos\theta - r$$

but

$$\cos\theta = D3/x$$

solving for D3 and substituting for cos , x, and r gives

$$D3 = s^2(1 - \cos\theta)/g\tan\phi$$

from which the basic equations can be summarized as:

$$D1 = (s)(T1)\sin\theta)$$
$$D2 = (s)(T2)(\sin\theta)$$
$$D3 = (s^2)(1 - \cos\theta)/g\tan\phi = .0527s^2(1 - \cos\theta)/\tan\phi$$

C.2.3 Relationship Between Surveillance Separation and Lateral Track Spacing

The Committee considered lateral track spacings of 30 nmi and agreed that automated surveillance would be required to support such spacings (except for one 30 nmi option). However, a minimum was not specified nor was the subject of surveillance separation addressed. Also, certain aspects of the application of surveillance in oceanic airspace, as initially envisioned by the Committee, have no clear precedent in at least the U.S. domestic airspace. In U.S. domestic airspace, routes are established with a minimum spacing of 8 nmi. The radar separation minimum (i.e., the SS) in the en route environment is 5 nmi. There is no direct relationship between the two values, that is, each was established independently of the other.

However, a key factor relating SS to lateral track spacing is the position update rate and the accuracy of radar. (It appears that there exists no exact precedent in at least the U.S. domestic system. The en route update interval of 10 to 12 seconds in the United States has been

chosen to adequately support the 5 nmi radar minimum. In purely operational terms, an update interval is adequate if, in that situation when nominal traffic loadings and spacings are in effect and a worst case deviation suddenly occurs, the system (controller) will have sufficient notice to evaluate the potential problem, determine the action required, and communicate that action to the pilot such that the pilot can execute the specified action prior to the SS being compromised. In lieu of the guidance given in the area, an approach that appears to be logical is developed and analyzed in the following sections.

C.2.4 Introduction to Surveillance Evaluation

Considering the potential value or performance of dependent surveillance requires that various parameters related to the operational system environment be estimated or postulated. These include:

- Assumed worst case (for dependent surveillance evaluation purposes) cross-track blunder.
- Minimum actual aircraft-to-aircraft spacing (MAS), not to be compromised.
- Surveillance separation (SS).
- Controller detection/evaluation of off-course deviation, formulation and transmission of corrective action message, and pilot reaction times.
- Assumed aircraft maneuver to correct off-course deviation.
- Assumed (non-blunder) error envelope of the aircraft navigation system performance capability.

Assumed Worst Case Cross-Track Blunder. This parameter is defined as a nonplanned or noncoordinated deviation away from the flight planned track. This parameter can be defined as either the angle or the cross-track speed of the deviation. The blunder case assumed for analysis was a 9.6 degree angle of deviation, which corresponds to a waypoint insertion error at OTS latitudes, and equals a crosstrack vetocity of 80 knots for an assumed aircraft velocity of 480 knots. The 80 knot cross-track error is equal to 1.33 nmi per minute. This error was used in the evaluation of dependent surveillance for the 30 nmi track separation case presented in a following section.

Minimum Actual Aircraft-to-Aircraft Spacing (MAS). As defined earlier, the MAS is the final protection buffer against system blunders, and its value is largely subjective. The value chosen for MAS is 4 nmi, which was derived in reference to the U.S. en route radar minimum of 5 nmi. While errors within the U.S. system of approximately 2 miles are considered possible for a given target's displayed position versus the

aircraft's actual position, the relative distance between two proximate targets at or near the same altitude has considerably less error. Assuming a relative error of 1 mile or less (i.e., the MSE is 1 nmi), the remaining 4 miles can be regarded as the MAS. Although this value of MAS was derived with reference to a specific radar separation, this value can be regarded as being totally system independent.

Surveillance Separation (SS). Within the dependent surveillance options being considered, the MSE is assumed to be, for analysis purposes, twice the 3 sigma error of the particular MNPS system that is specified. (The 3 sigma error is applicable to one aircraft; therefore, when the spacing between a pair of aircraft is considered, the potential errors of both aircraft must be included.) Following is the developed value for SS:

30 nmi track spacing;

(for MNPS(I), 3 sigma equals 9 nmi)

SS = MSE + MAS
SS = 2 (3 sigma) + MAS
SS = 2 (9) + 4
SS = 22 nmi

(For MNPS (I) the 1 sigma value selected was 3 nmi. Note, if the errors are independent, 3 sigma relative error protection is provided by SS = $\sqrt{2}$(3 sigma) + MAS.)

Controller Detection/Pilot Reaction Time Lapse. Determining an adequate update interval requires that the total time lapse between that point in time when a deviation first becomes potentially detectable by the controller and that point in time when the pilot reacts to the corrective action direction be taken into account. This total time has four component activity elements; the assumed associated time allocations are as follows:

1.	Controller detection/recognition of the deviation event	30 seconds
2.	Controller decision on remedial action and initiation of appropriate message to aircraft	30 seconds
3.	Communication channel acquisition/transmission time	15 seconds
4.	Pilot receipt/assimilation of the message and initiation of directed action	15 seconds
	Total	90 seconds (i.e., 1.5 min).

However, if an automatic system monitors and detects deviations beyond some threshold, the time allocation for Component 1 may be significantly less.

Assumed Aircraft Maneuver to Correct Off-Course Deviation. A 10 degree bank and associated coordinated turn maneuver was assumed for this parameter. Pilots stated at informal meetings during the Williamsburg Committee Meeting that such a maneuver would hardly be noticed by the passengers and would be very smooth. The cross- track distance traveled by an aircraft after initiating the coordinated turn was shown to be equal to:

$$D3 = s^2(1 - \cos\theta)/g\tan\phi$$

assuming s = 480 knots, θ = 9.6 degrees, and ϕ = 10 degrees, D3 = .27 nmi.

C.2.5 Quantitative Evaluation of Dependent Surveillance Function

For this analysis, a worst case situation between two aircraft is defined as follows: The two aircraft are directly across from each other on adjacent tracks at the same altitude, and one aircraft starts to deviate from the track at the assumed maximum blunder angle of 9.6 degrees (i.e., a cross-track speed of 80 knots, or at a 1.33 nmi per minute rate). The following analysis refers to the cross-track distances D1, D2, and D3 (defined and discussed earlier) that are associated with the cross-track error growth beginning with the start of deviation and continuing through to the point of maximum deviation.

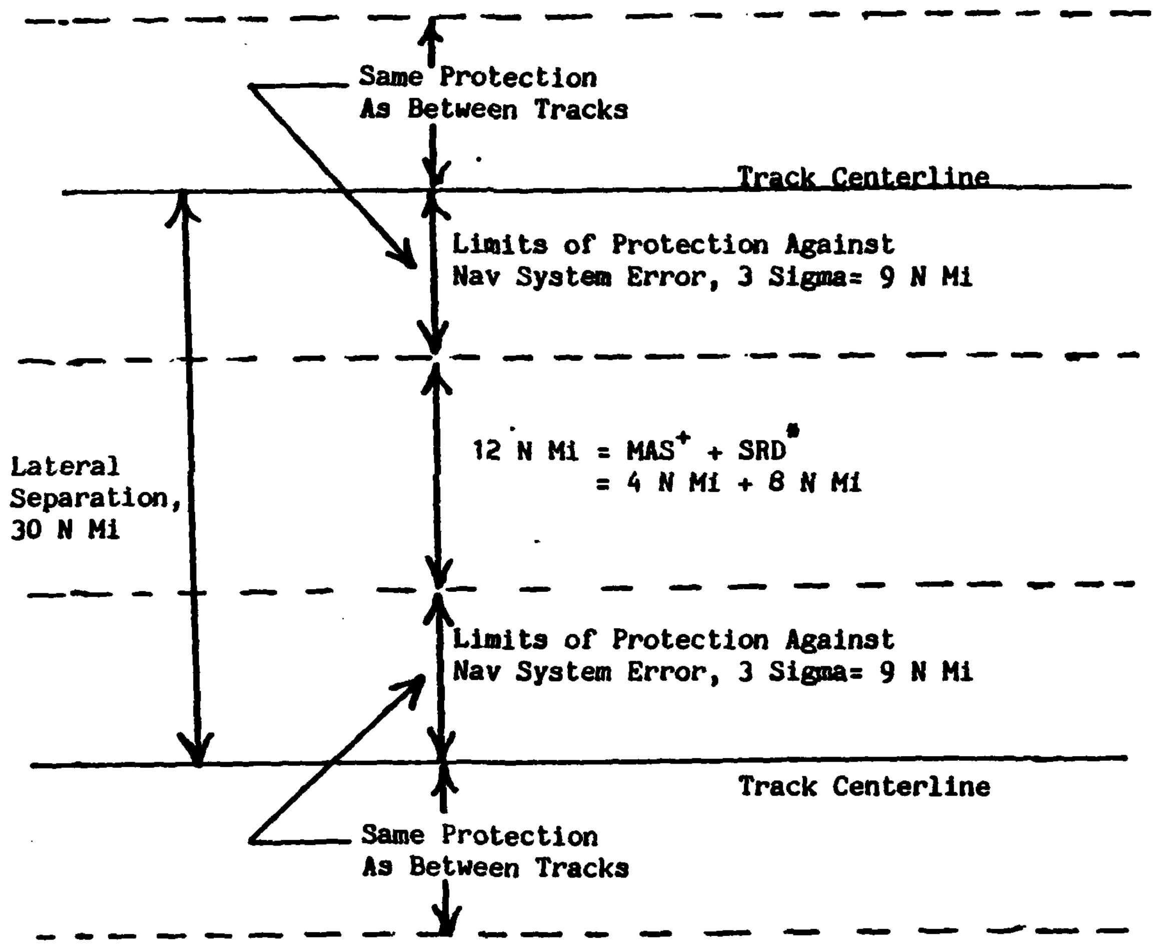
The surveillance reaction distance (SRD) is the maximum allowable cross-track distance that an aircraft can be allowed to fly during the blunder detection and corrective action time period so that the minimum separation will not be compromised. Thus,

SRD = Track spacing - 2 (3 sigma nav. error) - MAS, or
SRD = Track spacing - SS, and
SRD $\geq$ D1 + D2 + D3

Figure C-3 presents the basic geometry of the surveillance function. Following is a sample calculation carried out for the 30 nmi case.

Example: 30 nmi, 1 minute Update Rate, and 3 nmi (1 sigma)

$$\begin{aligned} SRD &= 30 - 2\ (3)\ (3) - 4 \\ &= 30 - 18 - 4 \\ &= 8 \text{ nmi} \end{aligned}$$



+ MAS May Float Within The 12 N Mi Interval
* D1 + D2 + D3 $\leq$ SRD For Any Deviation

Figure C-3: Basic Surveillance Function Geometry

D1 = 1.33 mile
D2 = 2.0 miles
D3 = .27 miles
Total = 3.6 nmi

SRD > D1 + D2 + D3 by 4.4 nmi, which corresponds to a margin of 3.3 minutes and, at an update rate of 1 minute, a margin of 3 surveillance updates. Figure C-4 shows a graphic view of the example presented.

Conclusion

As the calculation reveals, the dependent surveillance function with an update interval of 1 minute appears to be adequate to support a track spacing of 30 nmi, assuming the range of parameter values selected for the analysis. Although threshold limits have not been examined, there appears to be considerable margin to include such a limit in a satisfactory manner. Such aspects as the type and degree of undetected errors, and the level of navigational performance that can be met under an improved MNPS will impact the dependent surveillance function. In summary, the functional aspects and benefits of dependent surveillance will need to be more closely examined prior to any implementation.

C.3 Communications Requirements

The communications data flow requirements to aupport automatic dependent surveillance and other ATS functions were developed by WGB and reported in its report to the Committee (Ref. 1, ARC 80/WP-17). These requirements formed the basis of both HF and satellite data link design concepts. The key features of these requirements were stated to be:

1. The system is to support separation standards of 30 miles lateral, 5 minutes longitudinal, and 2000 ft vertical. (Note: A previous requirement to support 15 miles/2 minutes/2000 ft separation standards without a form of independent surveillance was deleted by the ARC.)

2. It shall provide the means of direct pilot-controller communications incorporating sufficient information to satisfy an automatic dependent surveillance function.

3. The dependent surveillance function will be satisfied by the derivation on board, and transmission air-to-ground, of aircraft position, (lat., long. and altitude).

4. The system shall also provide the means of exchanging communications for:

   1) Altitude clearance request and acknowledgement.
   2) Re-route clearance request and acknowledgement.
   3) Met. Reports.

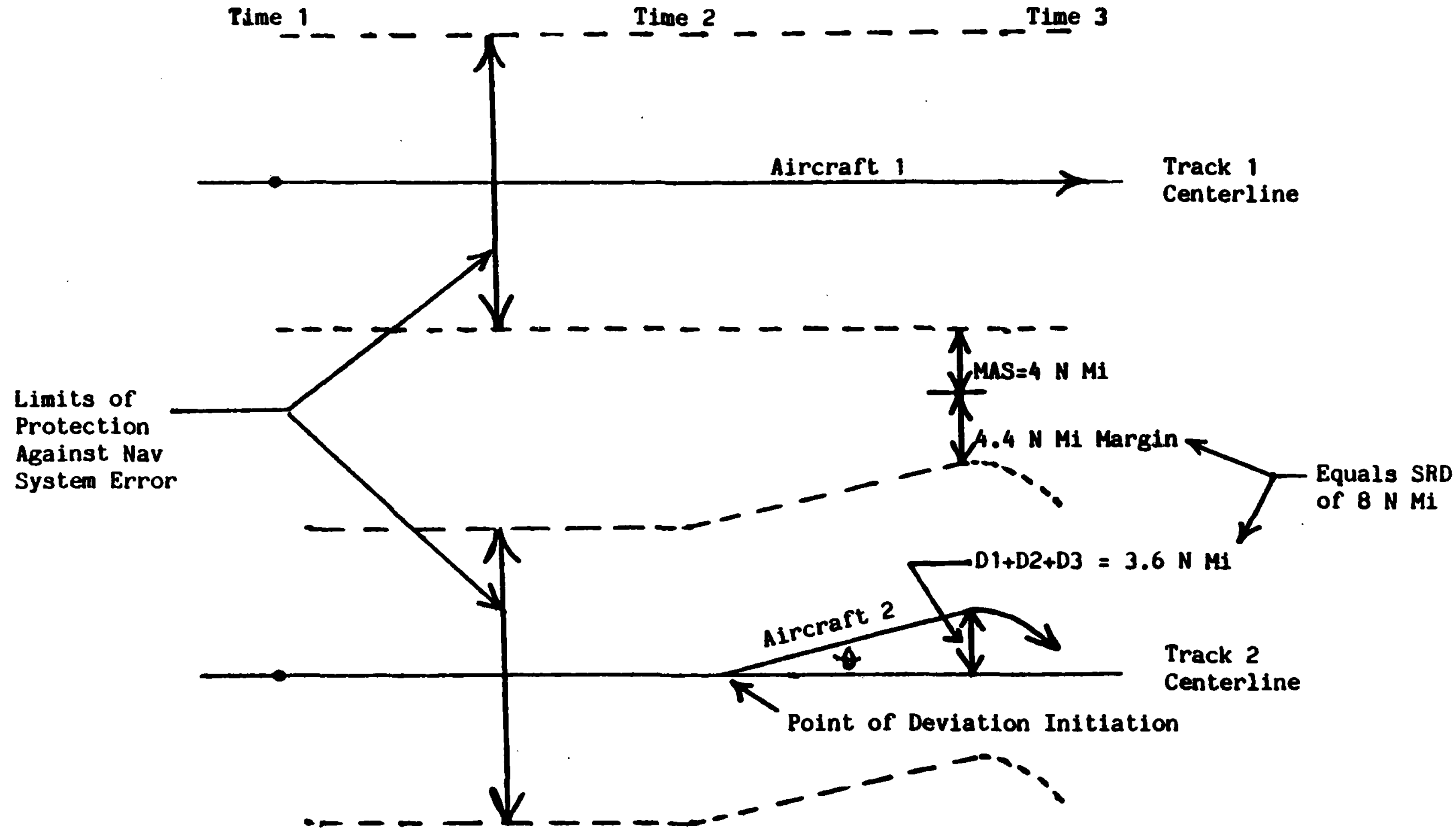


Figure C-4: Geometry of Surveillance Function For Sample Calculation Presented

4) Waypoint verification.
5) Other miscellaneous messages, including request for voice channel and abnormal operations alerting.

5. In addition the system shall be capable of exchanging special messages required during times when aircraft may be in close proximity, embracing:

   - Request and receipt of position up-date with associated kinematic data.

6. The information contents of the above communications are described in Tables C-1 through C-5.

7. The system shall cater for a peak instantaneous airborne count of 223 aircraft (representing year 2005) over the area embraced by the following FIRs: Gander, Shanwick, New York, Santa Maria, Reykjavik, San Juan (NAT) and Miami (NAT).

8. A polling system shall be used such that the normal interval between polls will be 5 mins, but during those periods in which aircraft are in proximity the polling rate may be 30 secs or 1 min or 2 mins, for only those aircraft in proximity.

9. Communications control of the system shall be shared between at least two ground stations to insure redundancy.

10. Provision shall also be made for the system to provide voice communications for emergencies and those types of communication which cannot be handled by the data system.

The estimated data flows that might be required to support a dependent surveillance function (ref. 2) are summarized below. The data flows are computed as a function of peak traffic (and proximate aircraft) counts, usable sampling frequencies calculated earlier, and the information contained in the messages transmitted within the closed-loop model.

Estimates for the communication system loading are based on forecasts of air traffic patterns in the year 2005. These forecasts were developed as part of the overall OASIS program effort (see ref. 3). The maximum instantaneous aircraft count, aircraft proximity count, and frequency of flights entering the system are based on results obtained from simulation runs of the Flight Cost Model (FCM) for the North Atlantic region (NAT) (see ref. 4).

The traffic levels applicable to evaluation of the surveillance function in the NAT are based on a simulation of a 30 nmi lateral track spacing scenario. The instantaneous aircraft count peaks at slightly more than 200 aircraft. Some variation exists in the peak based on the

Table C-1

TYPICAL DATA LINK MESSAGE COMPONENTS AND BIT LENGTHS

Message	Range	Bits Required	Bits Assumed
Latitude	-90.01 to + 90.01 Degrees	15	16
Longitude	-180.01 to + 180.01 Degrees	16	16
Time	00.00 to 24.00 Hrs.	13	13
Identification Code	0 to 999 (3 digits)	10	10
Altitude	(0 to 8192 ft) x 10 ten foot increments	13	13
Wind Direction	-180.01 to + 180.01 Degrees	16	16
Wind Velocity	0 to 200 Knots	8	8
Temperature	-100 to + 100 Degrees	7	7
Character	10 bits/character	10	10
Mach	(0-99 Mach) x .01	7	7
Codes*	1 to 256 Codes	8	8
TAS	0 to 2000 Knots	11	11
Distance	0 to 50 nmi	6	6

*Codes will include miscellaneous up and down requests.

Table C-2

ROUTINE REPORTS DOWN (AIRCRAFT-TO-GROUND)

Report	Average Frequency	Content	Bits
1. Position	5-10 min/flight	ID, Code, Lat, Lon Alt, Time	10 + 8 + 16 + 16 + 13 + 13 = 76
2. Alt Clearance Request	1/flight	ID, Code, Alt	10 + 8 + 13 = 31
3. Alt Clearance Acknowledgement	1/flight	" " "	10 + 8 + 13 = 31
4. Met Report	1/flight	ID, Code, Wind Dir., Wind Vel., time	10 + 8 + 16 + 8 + 13 = 55
5. Reroute Clearance Request	0.5/flight	ID, Code, 4 waypoints, Alt, Mach	10 + 8 + 8 x 16 + 13 + 7 = 266
6. Reroute Clearance	"	" " " " "	10 + 8 + 8 x 16 + 13 + 7 = 266
7. Waypoint Verification	4/flight	ID, Code, Next Waypoint, ETA Next Waypoint	10 + 8 + 16 + 16 + 13 = 63
8. Emergency	1/1000 flight	ID, Code	10 + 8 = 18
9. Miscellaneous Word Messages	0.5/flight	ID, Code, 240 characters	10 + 8 + 2400 = 2418

Table C-3

ROUTINE MESSAGES UP (GROUND-TO-AIRCRAFT)

Report	Average Freq.	Content	Bits
1. Position Request	5-10 min/flight	ID, Code	10 + 8 = 18
2. Alt Clearance	1/flight	ID, Code Alt	10 + 8 + 13 = 31
3. Reroute Clearance	0.5/flight	ID, Code, 4 waypoints Alt, Mach	10 + 8 + 8 x 16 + 13 + 7 = 266
4. Met. Advisory	1/flight	ID, Code, 120 characters	10 + 8 + 1200 = 1218
5. Miscellaneous Advisory	0.5/flight	ID, Code, 120 characters	10 + 8 + 1200 = 1218
6. Emergency Advisory (nearby Aircraft etc.)	1/500 flight	ID, Code, 120 characters	10 + 8 + 1200 = 1218

Table C-4

SPECIAL REPORTS DOWN LINK DURING PROXIMITY

Report	Frequency	Content	Bits*
1. Position Update with cross check	**	ID, Code, Lat, Lon, Alt Lat, Lon, Alt, Time	10 + 8 + 16 + 13 + 16 + 16 + 13 + 13 = 121
2. Position Update with kinematic data	**	ID, Code, Lat, Lon, Alt course heading, TAS, Time	10 + 8 + 16 + 16 + 13 + 16 + 11 + 13 = 103
3. Kinematic check	**	ID, Code, Lat, Lon Mag Hng, TAS, Time	10 + 8 + 16 + 16 + 16 + 11 + 13 = 90
			Avg = 104 Bits

*Note that frequent data can be shortened considerably by transmitting only the least significant bits that actually change.

**An average of one of these reports occurs every 30 seconds for each proximate aircraft or every 1 minute as appropriate.

Table C-5

SPECIAL REPORTS UP LINK DURING PROXIMITY

Report	Frequency	Content	Bits
1. Traffic Ahead(Behind)	1/flight	ID, Code, Miles	10 + 8 + 6 = 24
2. Traffic Lateral	1/flight	ID, Code, Miles	10 + 8 + 6 = 24
3. Traffic Below	1/flight	ID, Code, Alt, Miles	10 + 8 + 12 + 6 = 37
4. Off Course Warning	0.5/flight	ID, Code, Code, Param	10 + 8 + 6 + 6 = 30
5. Report Request	1.0 or 0.5 minutes for proximate flights	ID, Code	10 + 8 = 18
6. Emergency Deviation Request	1/1000 flights	ID, Code, 120 characters	10 + 8 + 1200 = 1218

exact definition of oceanic airspace. A peak of 229 occurs based strictly on FIR boundary definitions, 210 or so based on HF territory occupancy.

Aircraft proximity counts are based on a 5-minute nominal Mach number technique longitudinal separation in the 30 nmi FCM simulation. Including all aircraft on adjacent OTS tracks at the same flight level within 25 nmi longitudinally, approximately 37 aircraft are found to be in proximity at peak loading. Adding an additional factor of 90 percent for non-OTS flights, a total of 70 aircraft are estimated to be in proximity. (Note: Including all aircraft within this proximity plus all aircraft pairs within 50 nmi of each other on the same track could bring this number up to 116 aircraft.)

New aircraft entering the system are estimated by summing peak hourly entries in the Shanwick and San Juan FIRs, since most aircraft go through these FIRs. Peak is about 60 aircraft per hour, or about one each minute.

Sampling Nonproximate Aircraft. A nominal surveillance update rate is to be chosen for nonproximate aircraft. It is estimated that a sampling rate of once per 5 minutes is sufficient to satisfy this parameter.

Information flow is based on binary representations of data or characters that might be transmitted between an aircraft and a ground station. Table C-1 shows the lengths, in terms of number of bits required, of parameters that are commonly used for oceanic communication. It is assumed that data are transmitted without the use of any special conventions that might be applied to reduce flow rates. For example, data on time are presumed to be sent as a full word, and data on position as two complete words giving latitude and longitude, even though conventions could be used to avoid transmitting complete words for every item in every report or update. Tables C-2, C-3, C-4, and C-5 present the type, data content and frequency of occurrence of commonly used reports.

Tables C-6 and C-7 show type, frequency, and bit requirements for routine reporting. Note that position reporting requirements are based on instantaneous aircraft count and nominal position information sample rate. Other requiements are based on number of entries into the system each minute.

Table C-8 presents requirements for special high rate reporting appropriate to the approximate 70 aircraft affected. Frequencies are based on proximate aircraft count and are shown for update intervals of 1.0 and 0.5 minutes. The required information flow rates in both ground-to-aircraft and aircraft-to-ground direction and for the two polling rates assumed are summarized in Table C-9.

Table C-6

ROUTINE REPORTS: DOWN LINK REQUIREMENTS (5 MINUTE POLLING INTERVAL)

Report	Reports/Min Requirement	Bit Requirement (Bits/Sec)	Max Delay to Obtain Channel and Transmit
1. Position	210/5 = 42	42 x 76 x 60 = 53	15 sec
2. Alt Clearance	1 x 1 = 1	1 x 31/60 = .52	1 min
3. " Acknowl.	1 x 1 = 1	1 x 32/60 = .52	
4. Met Report	1 x 1 = 1	1 x 55/60 = .92	
5. Reroute Clearance Request	.5 x 1 = .5	.5 x 266/60 = 2.22	
6. Reroute Clearance	.5 x 1 = .5	.5 x 266/60 = 2.22	
7. Waypoint Verification	4 x 1 = 4	4 x 63/60 = 4.2	
8. Emergency	1 x 1/1000 = .001	.001 x 18/60 = 0	15 sec Lag:
9. Miscellaneous	.5 x 1 = 0.5	.5 x 2418/60 = 20	1 min
Total	51	84	

Routine Downlink Requirements: 84 bps

Table C-7

ROUTINE REPORTS: UP LINK REQUIREMENTS (5 MINUTE POLLING INTERVAL)

Report	Requirement Reports/Min	Requirement bits/second	Time to Send and Receive
1. Positions Request	210/5 = 42	42 x 18/60 = 12.6	15 sec
2. Altitude Clearance	1 x 1 = 1	1 x 31/60 = .52	1 min
3. Reroute Clearance	.5 x 1 = .15	.5 x 266/60 = 2.22	
4. Met Advisory	1 x 1 = 1	1 x 1218/60 = 20.	
5. Miscellaneous Advisory	0.5 x 1 = .5	0.5 x 1218/60 = 10	
6. Emergency	1/500 x 1~ 0	-	15 sec
Total	44	45	

Routine Uplink Requirements: 45 bps

Table C-8

INCREMENTAL DATA RATE REQUIREMENTS FOR PROXIMATE AIRCRAFT
(Special Uplink and Downlink Reports)

Report	Reports/Min		Bits/Sec	
	1 min/poll	.5 min/poll	1 min/poll	.5 min/poll
Down:				
Average of Reports 1,2,3,Special Reports During Proximity (Table C-4)	70 x 4/5 = 56*	70 x 9/5 = 126*	104 x 56/60 = 98	104 x 126/60 = 220
Totals	56	126	98	220
Up:				
1. Traffic check	1 x 1 = 1		1 x 24/60 = 0.4	
2. Traffic lateral	1 x 1 = 1		1 x 24/60 = 0.4	
3. Traffic below	1 x 1 = 1		1 x 37/60 = .62	
4. Off course warning	0.5 x 1 = 0.5		0.5 x 30/60 = .25	
5. Report Request	70 x 4/5 = 56*	70 x 9/5 = 126*	18 x 70/60 = 21	18 x 140/60 = 42
6. Emerging Deviation	1/1000 x 1 = 0		1/1000 x 1218/670 = 0	
Totals	60	130	20	40

*Number of proximate aircraft times the number of additional reports per aircraft per minute (Note: one report every 5 min is being provided through routine report requirements, see Table C-6).

Table C-9

SUMMARY OF REQUIRED DATA FLOW RATES

Composite Rates (Routine + Special for Proximity):

	1 min/poll	0.5 min/poll
Uplink	45 + 20 = 65 bps	45 + 40 = 85 bps
Downlink	84 + 98 = 182 bps	84 + 220 = 304 bps

Required Information Data Rates with 100% Overhead for Protocols:

	1 min/poll	0.5 min/poll
Uplink	130 bps	170 bps
Downlink	365 bps	610 bps

C.4 Estimates of Frequency of Warning with Airborne Separation Assurance Device and Surveillance

A careful analysis of intervention rate and alarm rate for an airborne separation assurance device or surveillance systems requires probabilistic models defining aircraft velocity error distributions. It also requires models of the types of proximities that would occur between aircraft in a nominal errorless environment. Such an analysis is beyond the scope of this effort. To obtain a first estimate on how such requirements may be drawn up a highly simplified and approximate methodology based on collision risk documentation (ref. 6) has been developed. The methodology simply estimates the order of magnitude of alarms that might result from a given system and establishes sensitivities of these parameters to characteristics of the operating environment. The results will only be used to indicate the value and direction of further development in this area.

C.4.1 Estimates of Frequency of Collision Warnings Likely to Occur with an Airborne Separation Assurance Device

To reduce the risk of collision between aircraft, airborne separation assurance devices may be installed. These devices measure the radial distance between two approaching aircraft, r, and the rate of approach, $\dot{r}$. The devices are typically set to trigger when the time before collision, τ, is less than 20 sec, i.e.,:

$$\tau = \frac{r}{\dot{r}} = \frac{1}{\boxed{80}} \text{ hr.} \qquad (1)$$

An adaptation of the basic collision risk model is employed in this section in an effort to estimate the frequency with which a tactical collision avoidance system might generate alarms to resolve potential collisions. The basic collision risk model provides an estimate of the frequency with which the actual separation between a pair of aircraft is reduced such that the box size dimensions assumed for the typical aircraft overlap, for a planned lateral separation between aircraft of S nmi. In the adaptation of the model in this section, a rough approximation of the frequency of collision-avoidance alarm is made by estimating the frequency with which the actual separation of a pair of aircraft becomes less than the dimensions of a box, the sides of which are determined from the parameter, τ, and present NAT estimates of the average relative speeds in each dimension, as a pair of aircraft are in the process of losing a planned lateral separation, S.

Ref. 2 analyzes the MNPS in the NAT. The double-double exponential function (Eq. 14, ref. 7) is used here to characterize the distribution of lateral deviation from course. The parameters of the function for

0.2 accidents for 10^7 flying hours are determined for 60 nmi separations. The results are given in Table C-10 for a sample case. Using these values, the overlap integral (Eq. 17, ref. 6) may be calculated for other values of track separation S.

Proximity Limits. The rectangular box surrounding an aircraft for alarm triggering is different from that simulated in the calculation of collision risk. Assuming two aircraft are on a head-on collision course along a track, the warning distance $\lambda_x(\text{opp})$ along the x axis is simply

$$\frac{\lambda_x(\text{opp})}{2} \times \frac{1}{|\overline{\dot{x}(\text{opp})}|} = \tau \tag{2a}$$

where $\lambda_x(\text{opp})$ is the average relative along-track speed of two aircraft flying in the opposite direction at the same flight level. Simplifying, we have

$$\lambda_x(\text{opp}) = 2|\overline{\dot{x}(\text{opp})}|\,\tau \tag{2b}$$

or

$$\frac{|\overline{\dot{x}(\text{opp})}|}{\lambda_x(\text{opp})} = \frac{1}{2\tau} \tag{2c}$$

Similarly we have

$$\begin{aligned} \lambda_x(\text{same}) &= 2|\dot{x}(\text{same})|\tau \\ \lambda_y &= 2|\overline{\dot{y}}|\tau \\ \lambda_z &= 2|\overline{\dot{z}}|\tau \end{aligned} \tag{3}$$

Using the values for velocities given in ref. 6 and τ of 20 sec, the values of λ_s are:

$$\lambda_x(\text{opp}) = 10.67 \text{ nmi}$$

$$\lambda_x(\text{same}) = 0.14 \text{ nmi}$$

$$\lambda_y = 0.52 \text{ nmi}$$

$$\lambda_z = .011 \text{ nmi}$$

We note that λ_y is much smaller when compared with S, the separation between tracks. Thus, Eq 2 of Ref. 6 is still valid. i.e.:

$$P_y(S) = 2\lambda_y C(S) \tag{4}$$

Table C-10

DETERMINATION OF LAMDA 1, LAMDA 2 AND ALPHA
WHICH SATISFY C(I) AND YIELD THE LOWEST ETA

C(I) = 0.000006452800000
SEPARATION STANDARD = 60. N.M.

LAMDA 2		LAMDA 1 (N.M.) 1.	2.	3.	4.	5.
29.	ALPHA =	0.0014802	0.0014749	0.0014653	0.0013850	0.0005488
	ETA =	0.0005261	0.0005245	0.0005661	0.0010446	0.0026725
30.	ALPHA =	0.0014293	0.0014246	0.0014158	0.0013390	0.0005310
	ETA =	0.0005258	0.0005244	0.0005662	0.0010449	0.0026728
31.	ALPHA =	0.0013848	0.0013805	0.0013725	0.0012987	0.0005153
	ETA =	0.0005261	0.0005248	0.0005668"	0.0010458	0.0026733

where

$$C(S) = \int_{-\infty}^{\infty} f(y) f(S - y) dy \tag{5}$$

and f(y) is the double-double exponential function mentioned earlier.

Frequency of Warning. Ref. 7 gives the derivation of the collision risk formula. The same derivation applies here. Let N_x denote the average number of times that an aircraft comes within longitudinal proximity overlap. The relative distance covered during a longitudinal proximity warning overlap is λ_x since departing aircraft are not in a proximity warning situation. Therefore, Eq. 2.1, Ref. 7, becomes

$$N_x = \frac{P_x}{t_x} = \frac{P_x |\overline{\dot{x}}|}{\lambda_x} \tag{6}$$

where P_x is the probability of longitudinal overlap, t_x is the average duration of a longitudinal overlap, and $|\overline{\dot{x}}|$ is the average of the absolute values of the relative longitudinal speed. Similar equations can be given for N_y and N_z. Denoting the number of proximity warnings per day as N_{ay}, we have using Eq. 1 of Ref. 6

$$N_{ay} = \frac{N_f P_y(S_y) P_z(0)}{S_y} \sum_{\substack{\text{same or} \\ \text{opposite}}} E_y \lambda_x \left(\frac{|\overline{\dot{x}}|}{\lambda_x} + \frac{|\overline{\dot{y}}|}{\lambda_y} + \frac{|\overline{\dot{z}}|}{\lambda_z} \right) \tag{7}$$

$$\left[E_y(\text{opp}) \, |\overline{\dot{x}(\text{opp})}| + E_y(\text{same}) \, |\overline{\dot{x}(\text{same})}| \right]$$

where

N_f = number of flying hours per day

$P_y(S_y)$ = probability of lateral overlap of aircraft nominally flying on laterally adjacent paths

S_y = the lateral separation standard

S_x = parameter used in calculation of the E_x values

E_y(same) = the average number of same-direction aircraft flying in laterally adjacent tracks at the same flight level within segments of length 2S centered on the typical aircraft

E_y(opp) = the average number of opposite direction aircraft flying on adjacent tracks at the same flight level within segments of length 2S centered on the typical aircraft

$P_z(0)$ = probability of vertical overlap of aircraft nominally flying at the same flight level.

Using Eq. 2, Eq. 7 becomes

$$N_{ay} = \frac{12 N_f \tau |\overline{\dot{y}}| C(S_y) P_z(0)}{S_x} \times \left[E_y(\text{opp}) |\overline{\dot{x}(\text{opp})}| + E_y(\text{same}) |\overline{\dot{x}(\text{same})}| \right] \quad (8)$$

where $C(S_y)$ is given by Eq. 5.

Numerical Values. In the determination of the numerical values of N_f, the values of the parameters given in ref. 2 are used. These are values used by NAT SPG for the traffic in 1973. They are given as follows:

S_x = 120 nmi

$E_y(\text{opp})$ = 0.013

$E_y(\text{same})$ = 0.5

N_f = 2000 hr

$P_z(0)$ = 0.25

$|\overline{\dot{y}}|$ = 47 knots

$|\overline{\dot{z}}|$ = 1 knot

$|\overline{\dot{x}(\text{opp})}|$ = 960 knots

$|\overline{\dot{x}(\text{same})}|$ = 13 knots

$C(S_y)$s was determined for different values of S_y using Eq. 17 of ref. 6, with one set of parameters that might have satisfied some NAT conditions. Section 4 contains the results plotted for this and several other reasonable sets of parameters, including those used in fixing NAT collision risk bounds.

C.4.2 Estimates of Frequency of Warnings for a Surveillance System

Very rough estimates of interventions that might occur with a surveillance system have been made using the same principles as those discussed in Section C.4.1. The difference between the surveillance and airborne separation assurance device calculations involve the proximate

distances at which an alert will occur. A case was calculated with $\lambda_x = 6$ nmi, $\lambda_y = 6$ nmi, and $\lambda_z = 1000$ feet and a case for $\lambda_x = 3$ nmi. This was chosen to represent an alert any time two aircraft came within 12 or 6 nmi laterally, 6 nmi longitudinally, and 2000 feet vertically.

Table C-11 and C-12 show the frequency of intervention estimated for three sets of navigation error assumptions consistent with several assumptions that could be made with the current NAT MNPS parameters, the observed MNPS parameters used for collision risk bounds, and another set consistent with the bounds.

References

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5. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume II: North Atlantic Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, II (September 1981).

6. "Analytical Development of a Minimum Navigation Performance Specification, Appendix A to the Report on Agenda Item 1.2: Report of the Limited North Atlantic Regional Air Navigation Meeting 1976," ICAO Doc 9182, LIM NAT pg 1.2-13 to 1.2-24, (1976).

7. "Description of A Model for Assessing the Collision Risk in Parallel ATS Route Structures: Methodology for the Deviation of Separation Minima Applied to the Spacing Between Parallel Tracks in ATS Route Structures," ICAO Circular 120-AN/89/2, Second Ed. pg 8-19, (1976).

Table C-11

NUMBER OF WARNINGS FOR
$\lambda_x = 6$ nmi, $\lambda_y = 6$ nmi, $\lambda_z = 1000$ ft

ALPHA = 0.001425 LAMDA 1 = 2.000000 LAMDA 2 = 30.000000

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.009968	100.320000 DAYS
50.	0.013910	71.890566 DAYS
40.	0.019419	51.496080 DAYS
30.	0.028029	35.677456 DAYS
20.	0.133955	7.465181 DAYS
15.	0.949851	1.052796 DAYS
10.	7.836928	0.127601 DAYS

ALPHA = 0.000870 LAMDA 1 = 4.450000 LAMDA 2 = 52.399990

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.009968	100.320000 DAYS
50.	0.023930	41.788986 DAYS
40.	0.120038	8.330667 DAYS
30.	0.806500	1.239925 DAYS
20.	5.335283	0.187431 DAYS
15.	13.031020	0.076740 DAYS
10.	29.755127	0.033608 DAYS

ALPHA = 0.001060 LAMDA 1 = 2.867000 LAMDA 2 = 52.399990

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.009968	100.320000 DAYS
50.	0.012127	82.463128 DAYS
40.	0.016349	61.164638 DAYS
30.	0.061656	16.219085 DAYS
20.	1.022822	0.977687 DAYS
15.	4.499328	0.222255 DAYS
10.	18.463261	0.054162 DAYS

Table C-12

NUMBER OF WARNINGS FOR
$\lambda_x = 6$ nmi, $\lambda_y = 3$ nmi, $\lambda_z = 1000$ ft

ALPHA = 0.001425 LAMDA 1 = 2.000000 LAMDA 2 = 30.000000

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.006929	144.324239 DAYS
50.	0.009669	103.424553 DAYS
40.	0.013498	74.084255 DAYS
30.	0.019483	51.326970 DAYS
20.	0.093112	10.739699 DAYS
15.	0.660243	1.514594 DAYS
10.	5.447461	0.183572 DAYS

ALPHA = 0.000870 LAMDA 1 = 4.450000 LAMDA 2 = 52.399990

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.006929	144.324239 DAYS
50.	0.016634	60.119254 DAYS
40.	0.083439	11.984820 DAYS
30.	0.560600	1.783804 DAYS
20.	3.708563	0.269646 DAYS
15.	9.057882	0.110401 DAYS
10.	20.682834	0.048349 DAYS

ALPHA = 0.001060 LAMDA 1 = 2.867000 LAMDA 2 = 52.399990

SEPARATION DISTANCE(NM)	NUMBER OF ALARMS PER DAY	FREQUENCY OF ALARMS(ONCE IN)
60.	0.006929	144.324239 DAYS
50.	0.008429	118.634651 DAYS
40.	0.011364	87.993818 DAYS
30.	0.042857	23.333404 DAYS
20.	0.710965	1.406539 DAYS
15.	3.127489	0.319745 DAYS
10.	12.833841	0.077919 DAYS

Appendix D

NAT USER FLIGHT COSTS SUPPORT DATA

D.1 Introduction

The following paragraphs describe the procedures used to estimate annual user flight costs for operating scenarios not simulated by the FCM. These scenarios represent potential sets of changes in separation standards as follows: (1) 60 nmi lateral/ 5 min longitudinal/2000 ft vertical; (2) 60 nmi/2 min/2000 ft; (3) 30 nmi/2 min/2000 ft; (4) 15 nmi/10 min/2000 ft; (5) 15 nmi/ 5 min/2000 ft; (6) 15 nmi/2 min/2000 ft; (7) 60-30 composite/10 min/2000 ft.

D.2 Derivation of Daily Costs

Except where noted, the figures below represent total daily flight costs for the July sample day in the indicated years. The breakdown of total costs into fuel and crew-and-maintenance components was based on analysis of FCM results that showed minimal changes in crew and maintenance costs among different 2000 ft vertical separation cases. The procedures used to convert July daily costs into annual costs are explained in Section D.3 below. In all cases below the costs are displayed for three years: 1979 1984 2005

D.2.1 60/5/2000 Case

Estimation of costs for 60/5/2000 involved an interpolation of costs from the FCM scenario 60/10/2000. Planned costs for 60/x/2000

	1979	1984	2005
were (US $ 000)	11,106	13,836	29,569
Actual costs for 60/15/2000 were	11,150	13,893	29,768
for a cost over planned (COP) of	44	57	199
Actual costs for 60/10/2000 were	11,136	13,878	19,734
for a COP of	30	42	165
The decrease in COP: (60/15 to 60/10)	32%	26%	17%

One alternative is to extrapolate using the above analysis. Another is as follows:

	1979	1984	2005
30/x/2000 planned costs	11,094	13,824	29,541
30/10/2000 actual costs were	11,120	13,860	29,682
for a COP of	26	36	141
30/5/2000 actual costs were	11,111	13,849	29,653
for a COP of	17	25	112
The decrease in COP (30/10 to 30/5)	35%	31%	21%

The decrease from 30/10 to 30/5 was presumed more appropriate to estimation of 60/5 from 60/10 because it is a better indication of the effects of halving longitudinal separation. Reducing 60/10/2000 COP by the 30/10 to 30/5 percentage decrease results in

estimated 60/5/2000 costs of	11,126	13,865	19,699
	11,126	13,865	19,699

D.2.2 60/2/2000 Case

As further reductions in separation minima are introduced, savings decrease in size, as was demonstrated by the figures above. Therefore, the actual costs have a lower limit, equal to the planned costs plus the costs of maintaining some nominal longitudinal separation. The nominal longitudinal separation indicated here is actually the Mach number technique separation, and non-Mach number aircraft must use some larger separation. At assumed levels of traffic, then, there will always be some congestion penalty above planned costs.

To derive the 60/2/2000 costs, assume that the proportion of savings to COP is equal to the average of the comparable savings previously calculated for 5 min longitudinal minimum reductions.

15 to 10 min (from 60 nmi)	32%	26%	17%
10 to 5 min (from 30 nmi)	35%	31%	21%
5 to 2 min (herewith proposed)	33%	28%	19%

Application of the above savings proportion to the 60/5/2000 costs results in estimated costs for the 60/2/2000 case of

11,119	13,857	19,674

D.2.3 30/2/2000 Case

Using the proportions derived for 60/2/2000 and applying them to 30/5/2000, the estimated costs for 30/2/2000 are

11,105	13,842	29,632

In these cases the planned costs are by method and by definition a lower bound to actual costs. In application, the lower bound is somewhat greater than the planned costs.

D.2.4 15/10/2000 Case

The above cases involved extrapolation on longitudinal separation. The next three scenarios will be based on lateral separation extrapolation. Just as planned costs act as a base and lower bound for actual costs, ideal flight costs serve as a base and lower bound to planned costs.

Ideal costs (from the FCM) were

	11,002	13,702	29,327

Planned costs for the 60/x/2000 case, again, were

	11,106	13,836	28,569
for a cost over ideal (COI) of	104	134	242
30/x/2000 planned costs were	11,094	13,824	29,541
for a COI of	92	122	214
The decrease in COI (60/x to 30/x)	12%	9%	12%

If the lateral separation, is halved again, no more proportional savings in the 30 to 15 nmi decrease than in the 60 to 30 nmi decrease. Using the above proportions, planned costs for 15/x/2000 are estimated to be

	11,083	13,813	29,515

Now a cost of congestion must be estimated. The cost of congestion, or COP, for 60/10/2000 was

	30	42	165
and COP for 30/10/2000	26	36	141

Assuming a similar reduction in congestion costs, the COP for

15/10/2000 is	22	30	117
and total costs of	11,105	43,843	29,632

D.2.5 15/5/2000 Case

Using the savings proportions of 30/10 to 30/5 on the 15/10 case,

the proportions being	35%	31%	21%
the 15/5/2000 COP is	14	21	91

and the estimates for total costs of the 15/5/2000 are

	11,097	13,834	29,607

D.2.6 15/2/2000 Case

In this case the savings proportions derived for 30/5 to

30/2 are appropriate:		28%	19%
for a 15/2/2000 COP of	9	13	69
and total costs of	11,092	13,828	29,589

D.2.7 60-30 composite/10/2000 Case

The costs for this scenario are assumed to be equal to the non-OTS costs for the 60/10/2000 case, plus the OTS costs for the 30/10/2000 case incremented by the percentage difference in OTS costs between the 60/15/2000 and the 120-60 composite/15/2000 cases.

In this derivation, costs are broken down into fuel and crew-and-mantenance (C&M) costs as follows:

	1979	1984	2005
	Fuel/C&M	Fuel/C&M	Fuel/C&M

for the standard indicated years of 1979, 1984, and 2005.

OTS costs for			
30/10/2000 are	4174/2302	5219/2699	10,263/4948
60/15/2000 are	4191/2305	5247/2711	10,320/4964
120-60/15/2000 are	4195/2304	5253/2711	10,340/4967

The percentage increase in OTS fuel costs from 60/15/2000 to 120-60/15/2000 is:

0.095%/-	0.114%/-	0.193%/-

Applying these increments to fuel costs for 30/10/2000 (C&M changes are estimated) gives the results

4178/2302	5225/2699	10,283/4950

which are the OTS costs for 60-30/10/2000.

The non-OTS costs for 60/10/2000 are:

2923/1727	3872/2075	9785/4678

Thus, the total costs for 60-30/10/2000 are:

7101/4029	9097/4774	20,068/9628

For comparison to other systems, the totals (fuel plus C&M) are:

11,130	13,871	29,696

D.3 Calculation of Annual Costs

Obtaining annual costs for all years 1979-2005 inclusive, beginning with July sample day costs for all cases and November sample day costs for the baseline 120-60/15/2000 case only, involves the steps described below. (Note: Only the 120-60/15/2000 case was simulated for the year 1995. Therefore, estimates were derived for all other scenarios for 1995.)

D.3.1 November Costs

Costs for the November sample day were based on the proportion of November to July costs in the baseline case. For fuel costs, these proportions were: 1979 - 0.7435; 1984 - 0.7017; 1995 - 0.6785; 2005 - 0.6522. For crew and maintenance costs, the proportions were: 1979 - 0.7210; 1984 - 0.7026; 1995 - 0.6849; 2005 - 0.6645.

D.3.2 Annual Costs

Actual recorded traffic statistics for the NAT for the years 1969 through 1979 were provided by IATA. These data were used to determine the weighting factors that were applied to the November and July daily cost figures in order to derive annual costs. The criterion for determining the weighting factors is minimization of total variation from actual annual air traffic over the 11-year period. A simple average of the two cost figures gave large variations from actual annual figures. However, a weighting of 65% of November costs and 35% of July costs resulted in a net variation of 0% for the aggregation of all 11 years as well as for 1979, the most recent year reported. Table D-1 summarizes the monthly traffic figures and variation percentages of the weighting method. The 65 - 35 weighting was used to annualize the November and July costs, and the weighted average was multiplied by a factor of 365 days/year.

D.3.3 Costs for Intermediate Years

Since the growths involved in costs are by nature compounded, interpolation between the calculated years (1979, 1984, 1995, and 2005) should also reflect compounded growth. Therefore, between each two calculated years (e.g., between 1979 and 1984 or between 1984 and 1995), intermediate values were calculated assuming a constant annual percentage growth in costs over the appropriate period.

Table D-1

ANNUAL DISTRIBUTION OF NAT TRAFFIC

	NAT Aircraft Movements (000)												Monthly	65/35	%
Yr	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Avg.	Avg.	Diff.
69	6.8	5.8	6.8	6.9	8.6	11.4	12.8	12.7	11.2	8.9	7.2	7.3	8.87	9.16	3
70	8.0	6.4	7.6	8.0	9.6	11.4	13.2	13.4	11.4	8.9	7.0	7.2	9.34	9.17	-2
71	7.4	6.2	7.4	8.0	9.5	11.2	12.5	12.7	11.0	9.6	7.5	7.5	9.21	9.25	0
72	7.2	6.6	7.7	8.1	9.6	10.5	12.4	12.6	11.0	9.6	7.4	7.4	9.18	9.15	0
73	7.4	7.0	9.6	8.8	10.3	11.4	12.8	12.8	11.4	10.3	7.1	6.2	9.59	9.10	-5
74	6.7	5.9	7.2	7.8	8.5	10.2	11.5	11.3	10.0	9.6	6.9	6.6	8.52	8.51	0
75	6.4	5.8	6.8	7.2	8.4	9.7	11.1	11.1	9.7	8.2	6.6	6.4	8.12	8.18	1
76	6.6	6.2	7.0	7.2	8.4	9.8	11.9	11.4	10.0	8.7	6.6	6.8	8.38	8.46	1
77	6.8	5.8	6.8	7.2	8.7	10.4	11.6	11.9	8.5	8.0	6.7	6.8	8.27	8.42	2
78	6.5	5.6	7.1	7.4	8.4	10.6	12.5	12.0	10.5	9.2	7.2	7.3	8.69	9.06	4
79	6.9	6.3	7.3	7.9	9.7	10.2	12.0	11.7	10.6	9.2	7.2	7.2	8.85	8.88	0
Avg	6.97	6.15	7.39	7.68	9.06	10.62	12.21	12.15	10.48	9.11	7.04	6.97	8.82	8.85	0

Appendix E

CEP USER FLIGHT COSTS SUPPORT DATA
(Prepared by David B. Koretz)

E.1 Introduction

This section describes the derivation of estimated user flight costs for two operating scenarios not simulated by the FCM. These scenarios represent potential sets of changes in CEP separation standards to (1) 15 nmi/2 min/2000 ft and (2) 50-25 nmi composite/ 10 min/2000 ft.

E.2 Derivation of Daily Costs

The cost figures shown in the following paragraphs are for the July sample day in the indicated years. In all cases figures shown are for the years 1979 1984 2005

E.2.1 15/2/2000 Case

Cost figures in this derivation are total costs, the sum of fuel and crew and maintenance (C&M) costs.

As discussed in Appendix D for the NAT region, ideal costs act as a base and lower bound to planned costs. The ideal costs for the CEP computed by the FCM were

(1979 US $ 000)	2784	4133	11145

The planned costs for each system were:

50/x/2000	2806	4166	11145
25/x/2000	2808	4165	11142

Following the trends in 1984 and 2005, and noting that the ORS rerouting costs in the 25/x/2000 are mitigated by the very close spacing of the 15 nmi case, planned costs for the 15/x/2000 are estimated to be: 2,806 4,164 11,139

To calculate total costs for the 15/2/2000 case, it is necessary to compute a cost over planned (COP) of having a 2 min nominal Mach numbe technique longitudinal separation.

The numbers can be extrapolated as follows:

50/10/2000 COP	8	11	45
25/10/2000 COP	9	10	38
estimated 15/10/2000 COP	8	9	32
25/5/2000 COP	8	8	30
estimated 15/5/2000 COP	7	7	25
estimated 15/2/2000 COP	6	6	20

estimated total costs for 15/2/2000:

2,812	4,170	11,159

Examination of the relationship between fuel and crew and maintenance components of costs in the CEP leads to a breakdown of the above costs as follows:

Fuel/C&M	Fuel/C&M	Fuel/C&M
1808/1004	2700/1470	7309/3850

E.2.2 50-25/10/2000 Case

The costs for the 50-25/10/2000 system are equal to the non-ORS costs for the 50/10/2000 case plus ORS costs for the 25/10/1000 case. (Note: There is minimal difference in ORS costs between the 50/15/2000 and the 100-50/15/2000, and it is presumed that the same would hold true for the ORS costs of the 50-25/10/2000 case relative to the 25/10/2000.)

Here the costs are broken down into fuel and C&M components:

25/10/2000 ORS costs	848/508	1139/661	2564/1419
50/10/2000 non-ORS costs	962/496	1568/808	4769/2429
total 50-25/10/2000	1810/1004	1707/1469	7333/3848

For comparison purposes, total July sample day costs are:

2,814	4,176	11,181

E.3 Calculation of Annual Costs

Unlike the NAT, CEP annual costs were based on a simple average of July and November sample day costs. Since November costs were obtained from the FCM only for the baseline 100-50/15/2000 case, November costs for other scenarios were estimated from the respective July figures based on the November to July cost proportions observed in the baseline scenario. Those proportions (of November cost to July costs) for fuel were: 1979 - 0.9018; 1984 - 0.8346; 1995 - 0.7947: 2005 - 0.8073. For crew and maintenance costs, the proportions were; 1979 - 0.9263; 1984 - 0.8734; 1995 - 0.8253; 2005 - 0.8360.

The simple averages of July and November costs for each year were multiplied by 365 to obtain annual costs. Figures for intermediate years were interpolated using the compounded-growth method for the NAT in Appendix D.

Appendix F

CAR USER FLIGHT COST SUPPORT DATA

Calculation of user flight costs for the Caribbean region using the FCM was precluded by lack of data and study resource limitations. this appendix presents alternative approach for determining preliminary estimates of the user flight costs of ATC intervention in potential conflict situations. Ref. 1 estimated the time spent by CAR aircraft flying 4000 ft below their chosen flight levels due to conflict resolution. Those results are summarized in Table F-1. Flight diversion times were estimated for the present system at 15 and 10 longitudinal min separations, and for several alternative scenarios that assumed radar coverage of the Miami to San Juan traffic corridor and various separation standards. It is assumed that aircraft in conflict must divert downward by 4000 ft since the flight level 2000 ft below would be reserved for traffic in the opposite direction.

Using the same fuel consumption tables that were used by the FCM, a weighted average of aircraft fuel consumption was derived based on the aircraft type mix of the published CAR flights schedules. The average amount of fuel consumed by an aircraft flying at FL 330 was determined to be 1.395 lb/nmi higher than that used by an aircraft flying at FL 370. Using an average airspeed of 480 knots, this figure calculated to 11.162 lb/min. The amount of fuel consumed because of the 4000 ft diversion is tabulated in Table F-2 for each FIR and for each ATS alternative.

The fuel cost tables used by the FCM showed February 1979 prices of about $71 per 1000 lb fuel in the United States and $76 per 1000 lb fuel in the Caribbean area. An average of $73.50 per 1000 lb plus the 29% inflation factor were used to derive a fuel cost of $94.815 per 1000 lb fuel for mid-1979. This price was applied to obtain the daily fuel costs of diversion shown in Table F-3.

The July 1979 sample day costs were multiplied by 365 to obtain the 1979 annual costs shown in Table F-4. The figures for the forecasted years are based on the traffic growth described in ref. 2. These figures assume 2.4% annual traffic growth from 1979 to 1995, and 2.0% annual growth from 1995 to 2005. These growth rates, when compounded, show a 78% total traffic growth from 1979 to 2005. It was assumed that diversion costs grow as the square of traffic growth because of pairwise interactions between potentially conflicting aircraft. Costs for the new operating alternative in Table F-4, a 2 min separation case, were extrapolated from the costs calculated in ref. 1. The computations deriving the costs in ref. 1 showed congestion to be roughly proportional to separations, and that relationship was assumed for the extrapolated scenario.

References

1. SRI International, "Oceanic Area System Improvement Study (OASIS) Volume IV: Caribbean Region Air Traffic Services System Description," Final Report No. FAA-EM-81-17, IV (September 1981).

2. SRI International, "Oceanic Area Systems Improvement Study (OASIS) Volume X: North Atlantic, Central East Pacific and Caribbean Regions Aviation Traffic Forecasts," Final Report No. FAA-EM-81-17, X (September 1981).

Table F-1

FIRST CUT ESTIMATE OF DAILY AIRCRAFT TIME SPENT IN DIVERSION, JULY 1979, CAR UPPER AIRSPACE

	Estimated Average Flight Time (Min)	Daily Duration of Diversion (Aircraft-Min)			
		15/10 min Separation	15/10 min Separation With Radar	10 Min Separation With Radar	5 min Separation With Radar
Houston CTA/FIR	45	122	122	77	36
Merida UTA/FIR	30	108	108	60	27
Miami (Gulf) CTA/FIR	15	2	2	2	-
Habana CTA/FIR	30	330	330	234	126
Port-au-Prince FIR†	15	75	75	38	15
Santo Domingo CTA/FIR	30	102	102	60	18
Miami (East CAR) CTA/FIR‡	60	810	*	*	*
Kingston CTA/FIR	30	96	96	75	48
San Juan (CAR) CTA/FIR‡	30	231	*	*	*
Curacao CTA/FIR	30	18	18	9	9
Piarco UTA/FIR‡	30	162	162	120	69
Maiquetia UTA/FIR	15	§	§	§	§
Total		2056	1015	675	348
Diversion Duration Factor		1.0	.49	.33	.17

*Radar coverage in Miami (East CAR) to San Juan (CAR) traffic corridor.

†The hypothetical divergence durations for the Port-au-Prince FIR assume provision of ATC service although ATC is not currently provided.

‡Excludes Piarco Atlantic Ocean FIR, Miami NAT and San Juan NAT air traffic.

§Negligible

Table F-2

FIRST CUT ESTIMATE OF FUEL SPENT IN DIVERSION, JULY 1979, CAR UPPER AIRSPACE

CTA/UTA/FIR	Daily Excess Fuel Usage Due to Diversion (Lb. of Fuel): 15/10 Min Separation	15/10 Min Separation With Radar	10 Min Separation With Radar	5 Min Separation With Radar
Houston CTA/FIR	1362	1362	859	402
Merida CTA/FIR	1205	1205	670	301
Miami (Gulf) CTA/FIR	22	22	22	-
Habana CTA/FIR	3683	3683	2612	1406
Port-au-Prince FIR†	837	837	424	167
Santo Domingo CTA/FIR	1139	1139	670	201
Miami (East CAR) CTA/FIR‡	9041	*	*	*
Kingston CTA/FIR	1072	1072	837	536
San Juan (CAR) CTA/FIR‡	2578	*	*	*
Curacao CTA/FIR	201	201	100	100
Piarco UTA/FIR‡	1808	1808	1339	770
Maiquetia UTA/FIR	§	§	§	§
Total	22948	11329	7533	3883

*Radar coverage in Miami (East CAR) to San Juan (CAR) traffic corridor.

†The hypothetical diversion durations for the Port-au-Prince FIR assume provision of ATC service although ATC is not currently provided.

‡Excludes Piarco Atlantic Ocean FIR, Miami NAT and San Juan NAT air traffic.

§ Negligible.

Table F-3

FIRST CUT ESTIMATE OF COST OF DIVERSION, JULY 1979, CAR UPPER AIRSPACE

CTA/UTA/FIR	Daily Cost of Diversion (1979 $ U.S.)			
	15/10 Min Separation	15/10 Min Separation With Radar	10 Min Separation With Radar	5 Min Separation With Radar
Houston CTA/FIR	129.14	129.14	81.44	38.12
Merida CTA/FIR	114.25	114.25	63.53	28.54
Miami (Gulf) CTA/FIR	2.09	2.09	2.09	-
Habana CTA/FIR	349.20	349.20	247.66	133.31
Port-au-Prince FIR†	79.36	79.36	40.20	15.83
Santo Domingo CTA/FIR	107.99	107.99	63.53	19.06
Miami (East CAR) CTA/FIR‡	857.22	*	*	*
Kingston CTA/FIR	101.64	101.64	69.36	50.82
San Juan (CAR) CTA/FIR‡	244.43	*	*	*
Curacao CTA/FIR	19.06	19.06	9.48	9.48
Piarco UTA/FIR‡	171.43	171.43	126.96	73.01
Maiquetia UTA/FIR	§	§	§	§
Total	2175.81	1074.16	714.25	368.17

*Radar installed in Miami (East CAR) to San Juan (CAR) corridor.

†The hypothetical diversion durations for the Port-au-Prince FIR assume provision of ATC service although ATC is not currently provided.

‡Excludes Piarco Atlantic Ocean FIR, Miami NAT and San Juan NAT air traffic.

§Negligible.

Table F-4

ANNUAL COST OF DIVERSION, JULY SAMPLE DAY, CAR UPPER AIRSPACE

Year	Annual Diversion Costs for Years Indicated (1979 US $)				
	15/10 Min Separation	15/10 Min Separation With Radar*	10 Min Separation With Radar*	5 Min Separation With Radar*	2 Min Separation With Radar*
1979	794,171	392,068	260,701	134,382	67,191
1980	832,388	411,307	273,494	140,976	70,488
1981	872,444	431,490	286,914	147,894	73,947
1982	914,428	452,663	300,993	155,151	77,576
1983	958,433	474,875	315,763	162,764	81,382
1984	1,004,554	498,177	331,257	170,751	85,376
1985	1,053,435	522,418	347,376	179,060	89,530
1986	1,104,695	547,839	364,279	187,773	93,887
1987	1,158,448	574,496	382,005	196,910	98,455
1988	1,214,818	602,451	400,593	206,491	103,246
1989	1,273,930	631,766	420,085	216,539	108,270
1990	1,335,919	662,507	440,526	227,075	113,538
1991	1,400,924	694,744	461,962	238,125	119,063
1992	1,469,092	728,550	484,441	249,712	124,856
1993	1,540,578	764,001	508,014	261,863	130,932
1994	1,615,541	801,177	532,733	274,605	137,303
1995	1,694,153	840,162	558,656	287,967	143,984
1996	1,762,746	874,179	581,275	299,626	149,813
1997	1,834,117	909,573	604,810	311,758	155,879
1998	1,908,378	946,400	629,298	324,380	162,191
1999	1,985,645	984,718	654,777	337,514	168,757
2000	2,066,040	1,024,588	681,288	351,179	175,590
2001	2,149,691	1,066,072	708,872	365,398	182,699
2002	2,236,728	1,109,235	737,573	380,192	190,096
2003	2,327,290	1,154,146	767,436	395,586	197,793
2004	2,421,518	1,200,876	798,508	411,602	205,801
2005	2,519,561	1,249,497	830,839	428,267	214,134

*Radar installed to cover Miami (East CAR) CTA/FIR to San Juan (CAR) CTA/FIR corridor.

APPENDIX G

PRELIMINARY CONFIGURATIONS AND REVISIONS

G.1 Configuration Revisions

A preliminary set of configurations were considered by the Aviation Review Committee at the 5th meeting of the Committee at Torremolinos (near Malaga), Spain, in December 1980 (ref. 1). These configurations are listed in Table G-1 as are the results of a preliminary cost analysis of the configurations. At the 5th meeting, the Aviation Review Committee revised the set of configurations to be considered in subsequent analysis and identifed areas of revision in the preliminary cost estimates (the revised configurations and costs are those presented in the main text of this report). The Committee's revisions to the preliminary configurations included deletions of a few configurations, additions of a few new configurations, modifications of a few other configurations, and retention without change of the remaining configurations. The results of the Committee's revisions are as described below as paraphrased from reference 2 using the Committee's revised configuration identification numbering system:

Configuration 1. Baseline, MNPS, 120-60/15/2000 through 1980, 60/15/2000 in 1981, 60/10/2000 in 1982 through 2005

Committee Action: This option was agreed an acceptable baseline on which to compare the following configurations and was retained.

Configuration 2a. 60-30 composite, MNPS, 60-30/10/2000 in 1985 (with no improvement in the vertical criteria)

Committee Action: This option was retained, but was considered less likely of achievement than 2b.

Configuration 2b. 60-30 composite, MNPS (Improved), and/or vertical PS 60-30/10/2000 in 1985

Committee Action: This option was introduced and retained but the 1985 implementation data was considered optimistic

Table G-1

PRELIMINARY CONFIGURATIONS:

NAT 1979-2005 PRESENT VALUE COST INCREMENTS BY CONFIGURATION RELATIVE TO BASELINE
(1979 Discounted US $ Millions)

Configuration[†]	User Net Cost: Capital Cost Increase	User Net Cost: Operating Cost Decrease	Provider Net Cost: Capital Cost Increase	Provider Net Cost: Operating Cost Decrease	User and Provider Net Cost[*]: Capital Cost Increase	User and Provider Net Cost[*]: Operating Cost Decrease	User and Provider Net Cost[*]: Total Cost Saving
1. Baseline, MNPS, 120-60/15/2000 through 1980, 60/15/2000 in 1981, 60/10/2000 in 1982 through 2005	0	0	0	0	0	0	0
2. 60-30 Composite, MNPS, 60-30/10/2000 in 1985	0	78	0	0	0	78	78
3. 60-30 Composite With Separation Assurance Device with 100% Avionics Capital Cost Allocation, MNPS, 60-30/10/2000 in 1989	64	65	1	0	65	65	1
4. 60-30 Composite With Separation Assurance Device with 50% Avionics Capital Cost Allocation, MNPS, 60-30/10/2000 in 1989	32	65	1	0	33	65	32
5. 1000 ft Vertical Separation Above FL 290 Oceanic Only, PS (Vertical), 60/10/1000 in 1985	0	453	6	0	6	453	448
6. 1000 ft Vertical Separation Above FL 290 Oceanic Only With Improved Altimetry, PS (Vertical), 60/10/1000 in 1988	11	403	6	0	17	403	387
7. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic PS (Vertical), 60/10/1000 in 1985	0	615	6	0	6	615	609
8. 1000 ft Vertical Separation Above FL 290 Oceanic and Domestic With Improved Altimetry, PS (Vertical), 60/10/1000 in 1988	11	545	6	0	17	545	528
9. Separation Assurance Device With 100% Avionics Capital Cost Allocation, MNPS (Improved), 30/5/2000 in 1990	64	176	1	0	65	175	111
10. Separation Assurance Device With 50% Avionics Capital Cost Allocation, MNPS (Improved), 30/5/2000 in 1990	32	176	1	0	33	175	143
11. Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30/5/2000 in 1990	26	167	38	78	65	244	180
12. Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30/5/2000 in 1990	64	167	65	107	129	274	145
13. Cooperative Independent Surveillance With Multiple Satellites Data Link and Voice, MNPS (Advanced), 15/2/2000 in 1995	51	222	58	75	109	296	187
14. Configuration 11 + Separation Assurance Device With 100% Avionics Capital Cost Allocation, MNPS (Advanced), 15/2/2000 in 1995	73	205	39	78	112	283	171
15. Configuration 12 + Separation Assurance Device With 100% Avionics Capital Cost Allocation, MNPS (Advanced), 15/2/2000 in 1995	110	205	66	107	176	312	136
16. Configuration 2 + Automatic Dependent Surveillance With Network HF Data Link and Voice, MNPS (Improved), 30/5/2000 in 1990	26	178	38	78	65	256	191
17. Configuration 2 + Automatic Dependent Surveillance With Satellite Data Link and Voice, MNPS (Improved), 30/5/2000 in 1990	64	178	65	107	129	285	156
18. Configuration 2 + Cooperative Independent Surveillance With Multiple Satellites Data Link and Voice, MNPS (Advanced), 15/2/2000 in 1995	51	248	58	75	109	323	214
19. Configuration 16 + Separation Assurance Device With 100% Avionics Capital Cost Allocation, MNPS (Advanced), 15/2/2000 in 1995	73	236	39	78	112	314	202
20. Configuration 17 + Separation Assurance Device With 100% Avionics Capital Cost Allocation, MNPS (Advanced), 15/2/2000 in 1995	110	236	66	107	176	343	167
21. Automatic Dependent Surveillance With Satellite Data Link Only, MNPS (Improved), 30/5/2000 in 1990	44	167	51	107	95	274	179
22. Simple HF Data Link and Voice Without Separation Minima Reduction, MNPS, Baseline Separation Minima	14	-16	29	88	43	71	29[§]
23. Simple HF Data Link and Voice With Separation Minima Reduction, MNPS (Improved), 30/5/2000 in 1990	26	167	29	88	55	254	200

[*]Discrepancies in addition are due to roundoff.

[†]The baseline system and separation minima are assumed in operation for each configuration until the further reductions indicated for the other configurations. Configurations 1-8 assume HF SSB voice air-ground communications and MNPS.

[§]The indicated net cost saving does not include any flight cost reductions due to better utilization of airspace and associated tactical control.

Configuration 3.	60-30 composite, airborne separation assurance device, 100% avionics cost allocation, MNPS, 60-30/10/2000 in 1989
Committee Action:	This option was deleted.
Configuration 4.	60-30 composite, airborne separation assurance device, 50% avionics cost allocation, MNPS, 60-30/10/2000 in 1989
Committee Action:	This option was deleted.
Configuration 5.	1000 ft vertical separation above FL 290, oceanic only, PS (vertical), 60/10/1000 in 1985
Committee Action:	This option was retained, but operational problems in transition areas were noted.
Configuration 6.	1000 ft vertical above FL 290, oceanic only, with improved altimetry, PS (vertical), 60/10/1000 in 1988
Committee Action:	This option was retained, but operational problems in transition areas were noted.
Configuration 7.	1000 ft vertical above FL 290, oceanic and domestic, PS (vertical), 60/10/1000 in 1985
Committee Action:	This option was retained, and was considered more attractive than option #5.
Configuration 8.	1000 ft vertical above FL 290, oceanic and domestic, with improved altimetry, PS (vertical), 60/10/1000 in 1988
Committee Action:	This option was retained, and was considered more attractive than option #6.
Configuration 9.	Airborne separation assurance device with 100% avionics cost allocation, MNPS (Improved), 30/5/2000 in 1990
Committee Action:	This option was retained with general support from all participants
Configuration 10.	Airborne separation assurance device with 50% avionics cost allocation, MNPS (Improved), 30/5/2000 in 1990

Committee Action:	This option was retained with general support from all participants noting that this option was more attractive than 9 due to 50% cost allocation.
Configuration 11a.	Automatic Dependent Surveillance with network HF data link and voice, MNPS (Improved), 30/5/2000 in 1990
Committee Action:	This option was retained with dissent from U.K. participant.
Configuration 11b.	Same as 11a with addition of airborne separation assurance device, with 50% avionics cost allocation
Committee Action.	This option was introduced and retained with dissent from U.K. participant.
Configuration 12a.	Automatic Dependent Surveillance with satellite data link and voice, MNPS (Improved), 30/5/2000 in 1990.
Committee Action.	This option was retained with dissent from U.K. participant.
Configuration 12b.	Same as 12a with airborne separation assurance device with 50% avionics cost allocation
Committee Action.	This option was introduced and retained with dissent from U.K. participant.
Configuration 13a.	Cooperative independent surveillance with multiple satellites data link and voice, MNPS (advanced), 15/2/2000 in 1995.
Committee Action.	Option retained.
Configuration 13b.	Same as 13a except adding freedom in the vertical plane.
Committee Action.	This option was introduced by the U.K. with descriptive material to be supplied by the U.K.
Configuration 14.	Configuration 11 and airborne separation assurance device, 100% avionics cost allocation, MNPS (advanced), 15/2/2000 in 1995.

Committee Action.	This option was deleted noting that cooperative independent surveillance is assumed to be required for 15/2/2000.
Configuration 15.	Configuration 12 and airborne separation assurance device, with 100% avionics cost, MNPS (advanced), 15/2/2000 in 1995.
Committee Action.	This option was deleted, same reason as 14.
Configuration 16.	Configuration 2a and Automatic Dependent Surveillance, Network HF data link and voice, MNPS (improved), 30/5/2000 in 1990.
Committee Action.	This option was deleted due to uncertainty in achieving option 2a in a timeframe significantly earlier than 1990.
Configuration 17.	Configuration 2a and Automatic Dependent Surveillance, satellite data link and voice, MNPS (improved), 30/5/2000 in 1990.
Committee Action.	This option was deleted, same reason as 16.
Configuration 18.	Configuration 2a and Cooperative Independent Surveillance, with Multiple Satellites, data link and voice, MNPS (advanced) 15/2/2000 in 1995.
Committee Action.	This option was retained, noting the doubts of some participants with regard to achievement of configuration 2a.
Configuration 19.	Configuration 16 and airborne separation assurance device, 100% avionics cost, MNPS (advanced), 15/2/2000 in 1995.
Committee Action.	This option was deleted, same reason as 14.
Configuration 20.	Configuration 17 and airborne separation assurance device, 100% avionics cost allocation, MNPS (advanced) 15/2/2000 in 1995.
Committee Action.	This option was deleted, same reason as 14.
Configuration 21a.	Automatic Dependent Surveillance, Satellite Data Link only, MNPS (improved), 30/5/2000 in 1990.

Committee Action.	This option was retained, noting that it would be more cost-effective than option 12a.
Configuration 21b.	Same as 21a with airborne separation assurance device, 50% cost allocation.
Committee Action.	This option was introduced and retained, noting that it would be more cost-effective than option 12b.
Configuration 22.	Simple network HF data link and voice without separation minima reduction, MNPS, automatic dependent surveillance, baseline separation minima.
Committee Action.	This option retained as a relatively early attainable step toward the attainment of improved oceanic air traffic control. (Note: Since the minimum satisfactory capability of the HF data link concept was subsequently perceived by Working Group B to be a simple network, this option has been changed to the simple network HF data link and voice concept.) control.
Configuration 23.	Simple HF data link and voice with separation minima reduction, MNPS (improved), automatic dependent surveillance, 30/5/2000 in 1990.
Committee Action.	This option was retained as an evolutionary step based on 22.
Configuration 24.	Same as 23 with an airborne separation assurance device.
Committee Action.	This option was introduced and retained noting that it would add further protection against the risk of collision.

Because of the various configuration deletions and insertions, the configuration numbering system given above was modified to that presented in the main text of the report. The correlation between the configuration numbering systems are as follows:

Preliminary Configuration Number	Revised Preliminary Configuration Number	Configuration Number
1	1 (retained)	1
2	2a (retained)	2
-	2b (introduced)	3
3	3 (deleted)	-
4	4 (deleted)	-
5	5 (retained)	4
6	6 (retained)	5
7	7 (retained)	6
8	8 (retained)	7
9	9 (retained)	8
10	10 (retained)	9
11	11a (retained)	10
-	11b (introduced)	11
12	12a (retained)	15
-	12b (introduced)	16
13	13a (retained)	19
-	13b (introduced)	20
14	14 (deleted)	-
15	15 (deleted)	-
16	16 (deleted)	-
17	17 (deleted)	-
18	18 (retained)	21
19	19 (deleted)	-
20	20 (deleted)	-
21	21a (retained)	17
-	21b (introduced)	18
22	22 (retained)	12
23	23 (retained)	13
-	24 (introduced)	14

G.2 References

1. Committee to Review the Application of Satellite and Other Techniques to Civil Aviation; "Report of the 5th Meeting of the Committee, 8-17 December, 1980, Torremolinos/ Malaga, Spain," (March 1981).

2. Federal Aviation Administration, draft manuscript, Office of Systems Engineering Management (February 1981).

APPENDIX H

RE-ASSESSMENT OF AERONAUTICAL SATELLITE COSTS

(Presented by the FAA, USA)

Source: Aviation Review Committee Working Paper ARC 81/WP-20, May 1980

AD-A123 896 OCEANIC AREA SYSTEM IMPROVEMENT STUDY (OASIS) VOLUME I 5/5
EXECUTIVE SUMMARY A..(U) SRI INTERNATIONAL MENLO PARK
CA G J COULURIS ET AL. SEP 81 OASIS FAA-EM-81-17-1

UNCLASSIFIED DOT-FA79WA-4265 F/G 17/7 NL

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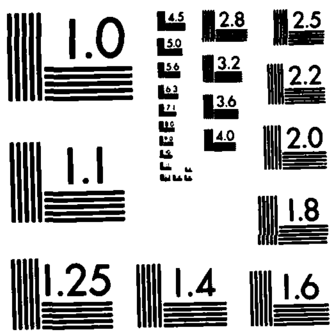

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COMMITTEE TO REVIEW THE APPLICATION OF SATELLITE AND OTHER TECHNIQUES TO CIVIL AVIATION

6th Meeting - Ottawa - May 1981

Agenda Item:

RE-ASSESSMENT OF AERONAUTICAL SATELLITE COSTS
(Presented by the United States)

INTRODUCTION AND SUMMARY

In its discussion of the OASIS Draft Final Report at the 5th meeting in Malaga, the ARC noted that costings based on optimum satellite sharing might result in overestimation of savings if it became necessary to resort to dedicated aeronautical satellites or to suboptimum sharing arrangements. A satellite-based cooperative independent surveillance system would probably require satellites dedicated to aeronautical service to ensure the necessary orbital locations and service level in a timely manner. For the data-and-voice or data-only service, an optimum sharing arrangement was used in the OASIS study where costs are based on the fraction of spacecraft mass used. It is possible that an aeronautical package for these services could cost more than the fraction of total spacecraft mass to satisfy the aeronautical service mission would suggest. This working paper re-examines the cost of dedicated aeronautical satellites (and associated launches) and suboptimum sharing arrangements. Most of these data were variously reported in working papers of Working Group B and were used in the preparation of the estimates for shared satellite services in the OASIS Final Report. Sharing of services appeared to be an important element in holding down the potential costs of a satellite repeater implementation because the envisioned alternative requirements (data-only, voice-and-data, or voice, data and cooperative independent surveillance) involve only a small payload.

The data presented in this working paper indicate that both development and recurring satellite and launch costs for dedicated satellites would increase about fourfold over the estimates for shared services used in the OASIS Final Report. The possibility that a 50 percent cost sharing arrangement might be necessary (i.e., pay 50 percent of a small satellite) to implement a data-and-voice or data-only capability was evaluated; this assumption corresponds to an increase by a factor of two to five in provider capital costs relative to optimum sharing for these alternatives.

The impact of this reassessment on net savings for configurations 15 through 21 is a reduction of \$61M for the data-only cases, \$47M for the voice-and-data cases, and \$122M for the multiple-satellite cooperative independent surveillance cases.

DEDICATED SATELLITE COSTS

The total development, unit, and launch costs of a dedicated satellite system for oceanic aeronautical use are derived in Appendix I and summarized below.

1. The development cost of a small (250 kg) geosynchronous aeronautical satellite is estimated to be \$29M. Development costs are typically expended at a uniform rate over a 3- to 4-year period.

2. The recurring unit satellite cost is estimated to be \$10M. The launch costs are in the neighborhood of \$12M for a Shuttle launch, \$18M for an Ariane launch, and \$22M for a Thor-Delta launch. A figure of \$18M for dedicated launch cost is used in all subsequent discussion. Recurring costs are incurred on the date of hardware delivery and/or launch.

NONOPTIMUM SHARED SATELLITE COSTS

Satellite costs might fall somewhere between the lower limits of optimum sharing as used in the OASIS Final Report and the dedicated satellite costs indicated above. This situation might arise in those configurations representing satellite voice-and-data service or in the satellite data-only service. To estimate the consequences of nonoptimum sharing, it is assumed that a 50 percent sharing ratio of the dedicated satellite and launch costs would obtain, or half the figures cited above.

IMPACT OF SATELLITE COST REVISIONS ON NET SAVINGS

The effect of revising satellite service cost upwards to reflect the possibility of nonoptimum sharing ratios is investigated. Two effects are modeled: (1) increase the space segment capital investment costs for Configurations 15 through 18 to be 50 percent of a dedicated satellite and (2) increase the space segment capital investment to 100 percent of a dedicated satellite for configurations 19 through 21. The results of this reassessment are presented in Table 1. The analysis for these results is given in Appendix II.

Table 1. Net Savings Comparison of Selected NAT Configurations Relative to Baseline (1979 Discounted US $ millions)

Configuration Number	Configuration Name	OASIS Net Savings	Reassessed Net Savings
15	ADS, SAT	145	98*
16	ADS, SAT, Separation Assurance Device - 50%	96	49*
17	ADS, SAT DL only	179	118*
18	ADS, SAT DL only, Separation Assurance Device - 50%	130	69*
19	CIS, MULTI SAT	187	65+
20	CIS, MULTI SAT, Free Vert Flight	253	130+
21	CIS, MULTI SAT, 60-30 C, MNPS	214	92+

*Assuming 50 percent of dedicated satellite costs.
+Assuming dedicated satellite costs.

APPENDIX I

DERIVATION OF SATELLITE AND LAUNCH COSTS

SPACECRAFT COSTS

Cost estimates are derived for a small geosynchronous satellite that could provide dedicated aeronautical communications and cooperative independent surveillance or provide aeronautical communication when shared equally with another service. There are many factors that influence the ultimate cost of a satellite communications service as was demonstrated by the AEROSAT program. In this program, institutional factors and constraints regarding the source of subsystem components, joint ownership, and lease arrangements contributed significantly to higher costs for the system. Based on recently developed requirements within the OASIS study, a dedicated aeronautical payload is considerably smaller than those commonly considered as small payloads. A small geosynchronous spacecraft is one in the SSUS-D* class, or a total of 350 to 450 kg mass. This mass includes spacecraft structure (bus), an apogee motor (apogee fuel is spent), power subsystem, an attitude control system (with adequate fuel supplies for north-south stationkeeping), thermal control system, telemetry subsystem, communications transponder payload and others. A spacecraft of this mass typically has a communications payload capacity of 70 to 100 kg, about four times the requirement identified in the OASIS program. As part of the study, a 25-kg communications payload was estimated to be adequate for the data-only or voice-and-data requirements identified. It is possible to estimate spacecraft cost by extrapolation of costs of similar kinds of satellites by weight. However, these extrapolations are not valid over a four-to-one weight range because the total spacecraft weight does not scale linearly with communication payload weight. Cost Estimating Relationships (CERs) are derived from historical data on the basis of a common definition of spacecraft type, weight, and a common base year in which the costs would have been incurred.** These kinds of estimates are preliminary because little design detail is available. With these cautions in mind, an estimate of the cost of dedicated aeronautical transponders of the size and capability characterized by Working Group B is suggested as follows. Assume that a 250-kg spacecraft would result from a dedicated aeronautical satellite development. This mass should be adequate to support the voice and data requirements developed in WGB as well as any additional payload weight increased to support cooperative

*Spinning Solid Upper Stage is an orbit transfer vehicle used with the space shuttle. An SSUS-D also serves as the third stage of a Thor-Delta launch vehicle, and an SSUS-A also serves as the third stage of an Atlas-Centaur launch vehicle.

**R.H. Sahmel, "Aeronautical Satellite Transponder Characteristics and Cost Estimates," The Aerospace Corporation, draft report, August 1980.

independent surveillance. This 250-kg mass compares with approximately 400 kg for AEROSAT and is within reasonable extrapolation range of developed CERs.

The nonrecurring or development cost estimate, C_d, using 1980 technology and given in 1980 U.S. dollars is:

$$
\begin{aligned}
C_d &= 0.33\ W^{0.678}\ (\$M) \\
W &= \text{dry spacecraft weight in lbs} \\
C_d &= \$24\ M.
\end{aligned}
$$

The recurring or unit cost estimate for a communications satellite of this weight is given by

$$
\begin{aligned}
C_r &= 0.079\ W^{0.731}\ (\$M) \\
&= \$8\ M.
\end{aligned}
$$

A slight downward trend in the cost of communications satellites (when adjusted for inflation) has been observed to amount to about 4 percent per year. This is attributed to productivity gains in the satellite industry. However, this effect is not modeled in the current cost analyses.

Uncertainties in the estimating procedures due to the scattering of the input data could account for cost variations of ±30 percent. Additional uncertainties regarding the nature of a specific aeronautical satellite procurement increases the uncertainty in these estimates beyond these limits. It is estimated that if a constrained procurement such as AEROSAT is envisioned, a 20 percent increase in both development costs and recurring costs would be realized. The estimated costs for a dedicated aeronautical satellite thus become

C_d: \$29 M

and

C_r: \$10 M

with an uncertainty of about 30 to 40 percent.

LAUNCH COSTS

The launch vehicle options for small civilian payloads to synchronous orbit altitudes will include the Space Shuttle and Ariane in the near future, and Thor-Delta vehicles for a limited time. The European launch vehicle Ariane can place 1700 kg into synchronous transfer orbit. Using the Systeme Lancement d'Ariane (SYLDA) in conjunction with the Ariane booster, two smaller payloads may be placed into synchronous orbit. The development of the Space Transportation System (STS) or Space Shuttle as it is commonly known, will end the era of expendable launch vehicles for most of the NASA-supported satellite projects as they are known today.

There are two kinds of upper stages that will be used to deliver satellite payloads beyond the Shuttle Orbiter's earth orbit. Large

payloads intended for geosynchronous, elliptic, or high circular orbits or destined for deep space may use the large, solid Inertial Upper Stage (IUS). Payloads of the Delta or Atlas-Centaur weight/volume class can use the Spinning Solid Upper Stage (SSUS), also known as Propulsion Assist Module (PAM), for transfer from the Shuttle to its final orbital position. The SSUS is designed to be compatible to a degree with these expendable launch vehicles to permit some programmatic flexibility as the Shuttle is being phased into service. The first Shuttle launch was tested successfully on April 12, 1981. Up to four test flights are scheduled before the Shuttle becomes operational in 1982. Additional Shuttle operational information is given in the attachment to this appendix.

The SSUS is designed to place into geosynchronous transfer orbit two primary classes of spacecraft: the Delta class, which ranges in mass from 2000 to a maximum of 2400 lb (900 to 1088 kg), including the Apogee Kick Motor (AKM), and the Atlas-Centaur class, which ranges in mass from 4000 to a maximum of 4400 lb (1800 to 1996 kg). It is expected that five Delta class (SSUS-D) or four Atlas-Centaur class (SSUS-A) stages with spacecraft can be carried on a single Shuttle flight. One or more SSUS/spacecraft may also share a flight with other Shuttle payloads.

Shuttle service options and use charges are still being developed by NASA. Estimates for the Shuttle launch are in the neighborhood of $20.0M in 1975 dollars. This cost would be shared by up to five users of a Delta-class vehicle.

The costs of the various satellite service alternatives are heavily dependent on the type of service provided; i.e., the size and complexity of the actual space borne communications payload, the launching arrangements, ground support, etc. In order to estimate these costs, an example of the launch costs for a dedicated aeronautical Delta-class satellite, using the Space Shuttle and the SSUS-D orbit transfer vehicle, is presented.

The basic Shuttle launch cost for the first three operational years has been fixed at $18.0M in 1975 dollars. Assuming that the Shuttle becomes operational in March 1982, the price will not change (in 1975 dollars) until October 1985. Most flights are already fully booked through 1984. Consequently, the $18.0M may jump by 25 percent or more for most projects not already in the definitive planning stages.

The Shuttle launch costs are divided among the various Shuttle payload users according to a cost factor formula prepared by NASA. The SSUS-D orbit transfer vehicle is expected to have a cost factor (CF) of about 0.2. The cost of the SSUS-D is expected to be in the range of $3M to $4M in 1980 dollars. There is a nonescalatable cost of $4.3M per Shuttle flight for nongovernment-use launches, subject to the cost-factor formula. In addition, there is a 10 percent optional services fee for processing geosynchronous satellites through the Kennedy Space Center, and there is a charge for reflight launch insurance. The cost escalation

used is based on actual Bureau of Labor statistics compensation rates through 1980 and a constant 8.5 percent beyond. Tables A-1 and A-2 summarize the projected launch cost of the above Delta-class geosynchronous satellite example.

Table A-1. Delta-Class Shuttle Launch Costs
(Dollar amounts in millions)

Dedicated Shuttle Operations Charge (1975 $)	$18.0
SSUS-D Launch Cost (CF = 0.2)	3.6
Optional Services (10 percent)	0.4
Reflight Insurance	0.1
Subtotal	4.1
Escalation to 1980 (x 1.57)	6.4
SSUS-D Purchase	4.0
Subtotal (1980 $)	10.4
Nongovernment-Use Fee (CF - 0.2)	0.9
Total Estimated Launch Cost (1980 $)	$11.3

After 1985, the launch costs excluding the SSUS-D purchase are expected to jump considerably because the government will attempt to recover its costs through user charges. CF is the cost factor discussed in the text.

Table A-2. Other Delta-Class Launch Costs
(Dollar amounts in millions)

Thor-Delta 3910/SSUS-D (1980 $)	$22.0
Ariane/SYLDA (1980 $)	18.5

ATTACHMENT TO APPENDIX I

SHUTTLE OPERATIONS SUMMARY

The basic inventory of the Shuttle consists of the Orbiter, several upper stage payload carriers, and spacelab.* The latter is an international project being undertaken by the European Space Agency.

The Shuttle operates by "flying" to a relatively low circular earth orbit from which all payload launch and retrieval operations are performed. Within the large cargo compartment (60 ft long by 15 ft diameter) may be affixed a number of satellite payloads, a payload release mechanism and/or a payload retrieval mechanism. For a Kennedy Space Center launch, the basic Shuttle characteristics are: 65,000 lb (29,500 kg); 160 nmi (300 km) altitude in a circular orbit; 28.5° inclination. The Orbiter provides a form of upper stage launch support by pointing each upper stage in the proper initial pointing direction. It also provides payload spin up, cooling services, supplemental electrical power, and payload functional checkout. The Orbiter flight control system provides a stability of ±0.1 degree per axis for any required reference attitude prior to upper stage release. The initial pointing, spin up, and release of the SSUS in the Shuttle Orbiter is similar to that function performed by the first two stages of the Delta three-stage launch vehicle. The SSUS performs the function of the Delta third stage for transfer orbit injection.

For a nominal geosynchronous mission, the Shuttle Orbiter places the payload into a 160-nmi (300-km) circular orbit inclined at 28.5°. After checkout, the SSUS and spacecraft are spun up and deployed by the Orbiter. Initial stabilization position, attitude, and the perigee velocity vectors are obtained from the Orbiter. The spin-up procedures are initiated and controlled from the Orbiter aft flight deck. Spin capability of up to 100 rpm for the SSUS-D and 65 rpm for the SSUS-A is available from the support equipment spin-up mechanism. After the SSUS and spacecraft are released, the Orbiter maneuvers to a safe distance. The SSUS and Orbiter coast in the parking orbit until the appropriate crossing of the Equator. At this time, the SSUS motor injects the SSUS/spacecraft into a 160- by 19,323-nmi (296- by 35,786-km) geosynchronous transfer orbit. The satellite is equipped with an integral AKM to perform the final phase of geosynchronous orbit injection. This is achieved through a velocity change that removes the 28.5° orbit inclination and simultaneously raises perigee to 19,300 nmi.

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*Space Transportation System User Handbook, National Aeronautics and Space Administration, June 1977.

APPENDIX II

DERIVATION OF NET SAVINGS IMPACT

The attached revised tables are taken from the OASIS Final Report, April 1981. Table 5-9A (Revised) reflects the cost of satellite provider costs if a 50 percent sharing of satellite cost were necessary. The incremental cost is transferred to Tables 8-16 and 8-18 to illustrate the additional discounted cost. The increase shown in Table 8-16 is applicable to both Configurations 15 and 16. Likewise, the increase shown in Table 8-18 applies to both Configurations 17 and 18. Table 5-15B (Revised) reflects the satellite provider costs for a fully dedicated satellite service. These costs are transferred to Table 8-20 for comparison. The cost increases shown in this table apply to Configurations 19 through 21.

The result of this incremental cost analysis is summarized in Table 9-6 (Revised) where the corresponding increases in provider capital cost and decreases in present value net savings for Configurations 15 through 21 are illustrated.

TABLE 5-9A (REVISED)

SATELLITE DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE NAT
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1980				
1981	1,500,000 (develop, test, spec.)			
1982	1,500,000 (develop, test, spec.)			
1983	5,000,000			
1984	5,000,000			
1985	5,000,000	978,400		
1986	19,000,000 (2 satellits including ground spare, 1 launch)	978,400	100,000	
1987		978,400	200,000	
1988	14,000,000 (1 sat, 1 launch)	978,400	400,000	250,000
1989			400,000	250,000
1990			400,000	250,000
1991			400,000	250,000
1992			400,000	250,000
1993	14,000,000 (1 sat, 1 launch)		400,000	250,000
1994			400,000	250,000
1995	14,000,000 (1 sat, 1 launch)		400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998			400,000	250,000
1999			400,000	250,000
2000	14,000,000 (1 sat, 1 launch)		400,000	250,000
2001			400,000	250,000
2002	14,000,000 (1 sat, 1 launch)		400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

TABLE 5-15B (REVISED)

COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE
PROVIDER COSTS FOR IMPLEMENTING AND OPERATING
THE GROUND AND SPACE SEGMENTS FOR THE NAT BEGIN IMPLEMENTATION IN 1986
(1979 US Dollars)

Year	Satellites	Ground Stations	Maintenance	Tracking, Telemetry & Command
1985				
1986	1,500,000 (develop, test, spec.)			
1987	1,500,000 (develop, test, spec.)			
1988	9,670,000			
1989	9,670,000			
1990	9,670,000	1,478,000		
1991	66,000,000 (3 sats including ground spare, 2 launches)	1,478,000	100,000	
1992		1,478,000	200,000	
1993	28,000,000 (1 sat, 1 launch)	1,478,000	400,000	250,000
1994			400,000	250,000
1995			400,000	250,000
1996			400,000	250,000
1997			400,000	250,000
1998	56,000,000 (2 SAT, 2 LAUNCHES)		400,000	250,000
1999			400,000	250,000
2000	28,000,000 (1 sat, 1 launch)		400,000	250,000
2001			400,000	250,000
2002			400,000	250,000
2003			400,000	250,000
2004			400,000	250,000
2005			400,000	250,000

TABLE 8-16 (REVISED)

COST SUMMARY FOR NAT CONFIGURATION 15:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER				COST INCREMENTS FOR 50% SHARING	
YEAR	CAP ITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAP ITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR	INCREMENTAL PROVIDER CAPITAL COSTS FOR YEAR INDICATED	DISCOUNTED 1979 PROVIDER CAPITAL COSTS
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979		
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980		
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981		
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982		
1983	7.533	0.000	7.533	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	41.413	3928.870	3970.283	1983	2.5	2.32
1984	7.533	0.000	7.533	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	42.163	4084.360	4126.520	1984	2.5	2.28
1985	8.511	0.000	8.511	11.30	24.20	35.50	23.380	1.112	24.492	2783.44	1453.98	4237.42	44.011	4261.906	4305.914	1985	2.5	2.24
1986	14.678	0.100	14.778	11.57	24.80	36.37	23.380	1.138	24.518	2893.03	1503.22	4396.25	51.148	4420.766	4471.910	1986	10.3	9.06
1987	8.978	0.200	9.178	11.85	25.40	37.25	23.380	1.165	24.545	3006.93	1554.14	4561.07	46.428	4585.609	4632.035	1987		
1988	6.678	0.650	7.328	12.13	26.00	38.13	1.731	1.193	2.924	3125.31	1606.77	4732.08	45.458	4735.000	4780.457	1988	8.3	7.04
1989	0.000	0.650	0.650	12.42	26.60	39.02	1.731	1.221	2.952	3248.36	1661.19	4909.55	39.670	4912.496	4952.164	1989		
1990	0.000	0.650	0.650	4.20	27.30	31.50	1.731	1.250	2.981	3366.74	1715.47	5082.21	32.150	5085.188	5117.336	1990		
1991	0.000	0.650	0.650	4.30	27.90	32.20	1.731	1.279	3.010	3499.08	1773.53	5272.61	32.850	5275.617	5308.465	1991		
1992	0.000	0.650	0.650	4.40	28.60	33.00	1.731	1.309	3.040	3636.62	1833.56	5470.18	33.650	5473.219	5506.867	1992		
1993	5.700	0.650	6.350	4.51	29.30	33.81	1.731	1.340	3.071	3779.56	1895.62	5675.18	40.160	5678.250	5718.406	1993	8.3	6.42
1994	0.000	0.650	0.650	4.62	30.00	34.62	1.731	1.372	3.103	3928.13	1959.79	5887.92	35.270	5891.020	5926.289	1994		
1995	6.700	0.650	7.350	4.73	30.70	35.43	1.731	1.404	3.135	4082.53	2026.12	6108.65	42.780	6111.781	6154.559	1995	8.3	6.19
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.731	1.437	3.168	4217.87	2088.82	6306.69	36.890	6309.855	6346.742	1996		
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.731	1.470	3.201	4357.70	2153.47	6511.17	37.810	6514.367	6552.176	1997		
1998	0.000	0.650	0.650	5.08	33.00	38.08	1.731	1.503	3.234	4502.16	2220.11	6722.27	38.730	6725.500	6764.227	1998		
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.731	1.539	3.269	4651.41	2288.82	6940.23	39.550	6943.492	6983.039	1999		
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.731	1.573	3.304	4805.61	2359.65	7165.26	47.270	7168.559	7215.828	2000	8.3	5.65
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.731	1.610	3.341	4964.93	2432.68	7397.61	41.500	7400.949	7442.445	2001		
2002	5.700	0.650	6.350	5.5[illegible]	36.20	41.78	1.731	1.647	3.378	5129.52	2507.96	7637.48	48.130	7640.852	7688.980	2002	8.3	5.44
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.731	1.6[illegible]4	3.415	5299.55	2585.58	7885.13	43.470	7888.543	7932.012	2003		
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.731	1.723	3.454	5475.26	2665.60	8140.06	44.500	8144.313	8188.809	2004		
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.731	1.763	3.494	5656.77	2748.09	8404.86	46.540	8408.352	8454.891	2005		
																		46.64*

* NET REDUCTION IN SAVINGS

TABLE 8-18 (REVISED)

COST SUMMARY FOR NAT CONFIGURATION 17:
AUTOMATIC DEPENDENT SURVEILLANCE WITH SATELLITE, DATA LINK ONLY

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER				COST INCREMENTS FOR 50% SHARING	
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR	INCREMENTAL PROVIDER CAPITAL COSTS FOR YEAR INDICATED	DISCOUNTED 1979 PROVIDER CAPITAL COSTS
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979		
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980		
1981	1.500	0.000	1.500	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	33.780	3640.390	3674.170	1981		
1982	1.500	0.000	1.500	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	34.520	3779.420	3813.940	1982		
1983	6.490	0.000	6.490	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	40.370	3928.870	3969.240	1983	3.5	3.25
1984	6.490	0.000	6.490	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	41.120	4084.360	4125.477	1984	3.5	3.19
1985	7.468	0.000	7.468	11.30	24.20	35.50	16.074	1.112	17.186	2783.44	1453.98	4237.42	42.968	4254.602	4297.566	1985	3.5	3.14
1986	10.728	0.100	10.828	11.57	24.80	36.37	16.074	1.138	17.212	2893.03	1503.22	4396.25	47.198	4413.461	4460.656	1986	14.3	12.46
1987	8.978	0.200	9.178	11.85	25.40	37.25	16.074	1.165	17.239	3006.93	1554.14	4561.07	46.428	4578.305	4624.730	1987		
1988	4.328	0.650	4.978	12.13	26.00	38.13	1.177	1.193	2.370	3125.31	1606.77	4732.08	43.108	4734.445	4777.551	1988	10.7	8.95
1989	0.000	0.650	0.650	12.42	26.60	39.02	1.177	1.221	2.398	3248.36	1661.19	4909.55	39.670	4911.941	4951.609	1989		
1990	0.000	0.650	0.650	4.20	27.30	31.50	1.177	1.250	2.427	3366.74	1715.47	5082.21	32.150	5084.633	5116.781	1990		
1991	0.000	0.650	0.650	4.30	27.90	32.20	1.177	1.279	2.456	3499.08	1773.53	5272.61	32.850	5275.063	5307.910	1991		
1992	0.000	0.650	0.650	4.40	28.60	33.00	1.177	1.309	2.486	3636.62	1833.56	5470.18	33.650	5472.664	5506.313	1992		
1993	3.350	0.650	4.000	4.51	29.30	33.81	1.177	1.340	2.517	3779.56	1895.62	5675.18	37.810	5677.695	5715.504	1993	10.7	8.20
1994	0.000	0.650	0.650	4.62	30.00	34.62	1.177	1.372	2.549	3928.13	1959.79	5887.92	35.270	5890.465	5925.734	1994		
1995	4.350	0.650	5.000	4.73	30.70	35.43	1.177	1.404	2.581	4082.53	2026.12	6108.65	40.430	6111.227	6151.656	1995	10.7	7.86
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.177	1.437	2.614	4217.87	2088.82	6306.69	36.890	6309.301	6346.188	1996		
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.177	1.470	2.647	4357.70	2153.47	6511.17	37.810	6513.813	6551.621	1997		
1998	0.000	0.650	0.650	5.08	33.00	38.08	1.177	1.503	2.680	4502.16	2220.11	6722.27	38.730	6724.949	6763.676	1998		
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.177	1.538	2.715	4651.41	2288.82	6940.23	39.550	6942.941	6982.488	1999		
2000	4.350	0.650	5.000	5.32	34.60	39.92	1.177	1.573	2.750	4805.61	2359.65	7165.26	44.920	7168.008	7212.926	2000	10.7	7.27
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.177	1.610	2.787	4964.93	2432.68	7397.61	41.500	7400.395	7441.891	2001		
2002	3.350	0.650	4.000	5.58	36.20	41.78	1.177	1.647	2.824	5129.52	2507.96	7637.48	45.780	7640.297	7686.074	2002	10.7	6.95
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.177	1.684	2.861	5299.55	2585.58	7885.13	43.470	7887.988	7931.457	2003		
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.177	1.723	2.900	5475.26	2665.60	8140.86	44.500	8143.755	8188.254	2004		
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.177	1.763	2.940	5656.77	2748.09	8404.86	46.540	8407.797	8454.336	2005		
																		61.27*

*NET REDUCTION IN SAVINGS

TABLE 8-20 (REVISED)
COST SUMMARY FOR NAT CONFIGURATION 19:
COOPERATIVE INDEPENDENT SURVEILLANCE WITH MULTIPLE SATELLITE
DATA LINK AND VOICE

ESTIMATED OUTLAYS (1979 US$ MILLIONS)

	PROVIDER SYSTEM IMPROVEMENT			PROVIDER FACILITIES ANNUAL O & M			USER AVIONICS IMPROVEMENT			USER FLIGHT O & M			PROVIDER AND USER				COST INCREMENTS FOR DEDICATED SATELLITES	
YEAR	CAPITAL	O & M	SUB TOTAL	COM	ATS	SUB TOTAL	CAPITAL	O & M	SUB TOTAL	FUEL	CREW & MAINT	SUB TOTAL	PROVIDER TOTAL	USER TOTAL	TOTAL	YEAR	INCREMENTAL PROVIDER CAPITAL COSTS FOR YEAR INDICATED	DISCOUNTED 1979 PROVIDER CAPITAL COSTS
1979	0.000	0.000	0.000	9.80	21.00	30.80	0.000	0.000	0.000	2168.47	1203.41	3371.88	30.800	3371.880	3402.680	1979		
1980	0.000	0.000	0.000	10.04	21.50	31.54	0.000	0.000	0.000	2263.32	1241.44	3504.76	31.540	3504.760	3536.300	1980		
1981	0.000	0.000	0.000	10.28	22.00	32.28	0.000	0.000	0.000	2358.62	1281.77	3640.39	32.280	3640.390	3672.670	1981		
1982	0.000	0.000	0.000	10.52	22.50	33.02	0.000	0.000	0.000	2458.22	1321.20	3779.42	33.020	3779.420	3812.440	1982		
1983	0.000	0.000	0.000	10.78	23.10	33.88	0.000	0.000	0.000	2565.76	1363.11	3928.87	33.880	3928.870	3962.750	1983		
1984	0.000	0.000	0.000	11.03	23.60	34.63	0.000	0.000	0.000	2678.01	1406.35	4084.36	34.630	4084.360	4118.989	1984		
1985	0.000	0.000	0.000	11.30	24.20	35.50	0.000	0.000	0.000	2783.44	1453.98	4237.42	35.500	4237.418	4272.914	1985		
1986	1.500	0.000	1.500	11.57	24.80	36.37	0.000	0.000	0.000	2893.03	1503.22	4396.25	37.870	4396.250	4434.117	1986		
1987	1.500	0.000	1.500	11.85	25.40	37.25	0.000	0.000	0.000	3006.93	1554.14	4561.07	38.750	4561.066	4599.813	1987		
1988	7.533	0.000	7.533	12.13	26.00	38.13	0.000	0.000	0.000	3125.31	1606.77	4732.08	45.663	4732.078	4777.738	1988	7.14	6.00
1989	7.533	0.000	7.533	12.42	26.60	39.02	0.000	0.000	0.000	3248.36	1661.19	4909.55	46.553	4909.547	4956.098	1989	7.14	5.88
1990	9.011	0.000	9.011	12.72	27.30	40.02	28.928	1.250	30.178	3376.25	1717.45	5093.70	49.031	5123.875	5172.902	1990	7.14	5.78
1991	20.678	0.100	20.778	13.03	27.90	40.93	28.928	1.279	30.207	3509.17	1775.62	5284.79	61.708	5314.992	5376.699	1991	51.80	41.18
1992	10.478	0.200	10.678	13.34	28.60	41.94	28.928	1.309	30.237	3647.33	1835.76	5483.09	52.618	5513.324	5565.941	1992		
1993	7.178	0.650	7.828	13.66	29.30	42.96	1.904	1.340	3.244	3790.92	1897.93	5688.85	50.788	5692.090	5742.875	1993	22 3[illegible]	17.09
1994	0.000	0.650	0.650	13.99	30.00	43.99	1.904	1.372	3.276	3940.17	1962.21	5902.38	44.640	5905.652	5950.289	1994		
1995	0.000	0.650	0.650	4.73	30.70	35.43	1.904	1.404	3.308	4073.61	2025.31	6098.92	36.080	6102.223	6138.301	1995		
1996	0.000	0.650	0.650	4.84	31.40	36.24	1.904	1.437	3.341	4208.31	2087.97	6296.28	36.890	6299.617	6336.504	1996		
1997	0.000	0.650	0.650	4.96	32.20	37.16	1.904	1.470	3.374	4347.47	2152.56	6500.03	37.810	6503.398	6541.207	1997		
1998	11.400	0.650	12.050	5.08	33.00	38.08	1.904	1.503	3.407	4491.22	2219.16	6710.38	50.130	6713.781	6763.910	1998	44.60	31.14
1999	0.000	0.650	0.650	5.20	33.70	38.90	1.904	1.538	3.442	4639.73	2287.81	6927.54	39.550	6930.980	6970.527	1999		
2000	6.700	0.650	7.350	5.32	34.60	39.92	1.904	1.573	3.477	4793.16	2358.59	7151.75	47.270	7155.227	7202.496	2000	22.30	15.03
2001	0.000	0.650	0.650	5.45	35.40	40.85	1.904	1.610	3.514	4951.65	2431.56	7383.21	41.500	7386.719	7428.215	2001		
2002	0.000	0.650	0.650	5.58	36.20	41.78	1.904	1.647	3.551	5115.39	2506.78	7622.17	42.430	7625.719	7668.148	2002		
2003	0.000	0.650	0.650	5.72	37.10	42.82	1.904	1.684	3.588	5284.54	2584.33	7868.87	43.470	7872.453	7915.922	2003		
2004	0.000	0.650	0.650	5.85	38.00	43.85	1.904	1.723	3.627	5459.28	2664.28	8123.56	44.500	8127.184	8171.680	2004		
2005	1.000	0.650	1.650	5.99	38.90	44.89	1.904	1.763	3.667	5639.80	2746.71	8386.51	46.540	8390.172	8436.711	2005		
																		122.14*

*NET REDUCTION IN SAVINGS

TABLE 9-6 (REVISED)

PRESENT VALUE 1979-2005 NET SAVINGS FOR EACH NAT CONFIGURATION RELATIVE TO BASELINE
(1979 DISCOUNTED US $ MILLIONS)

CONFIG-URATION NUMBER	USERS CAPITAL COST	USERS OPERATING COST	USERS TOTAL COST	PROVIDERS CAPITAL COST	PROVIDERS OPERATING COST	PROVIDERS TOTAL COST	USERS + PROVIDERS CAPITAL COST	USERS + PROVIDERS OPERATING COST	USERS + PROVIDERS TOTAL	CONFIG-URATION NAME
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	BASELINE
2	0.	78.	78.	0.	0.	0.	0.	78.	78.	60-30 COMPOSITE, MNPS
3	0.	78.	78.	0.	0.	0.	0.	78.	78.	60-30 COMPOSITE, MNPS(I)
4	0.	453.	453.	-6.	0.	-6.	-6.	453.	448.	1000 FT OCEANIC
5	-11.	403.	392.	-6.	0.	-6.	-17.	403.	387.	1000 FT OCEANIC + ALTIMETRY
6	0.	615.	615.	-6.	0.	-6.	-6.	615.	609.	1000 FT EVERYWHERE
7	-11.	545.	534.	-6.	0.	-6.	-17.	545.	528.	1000 FT EVERYWHERE + ALTIMETRY
8	-64.	167.	103.	-1.	0.	-1.	-65.	167.	102.	SEP AS DEV, 100% AVIONICS COST
9	-32.	167.	135.	-1.	0.	-1.	-33.	167.	134.	SEP AS DEV, 50% AVIONICS COST
10	-54.	167.	113.	-40.	78.	38.	-94.	244.	150.	ADS, NETWORK HF
11	-86.	150.	65.	-41.	78.	37.	-127.	228.	101.	ADS, NETWORK HF, SEP AS DEV-50%
12	-24.	-16.	-41.	-33.	92.	59.	-57.	75.	18.	SIMPLE HF,NO SEP MIN REDUCTION
13	-43.	138.	95.	-33.	92.	59.	-76.	230.	154.	SIMPLE HF,MIN RED
14	-78.	124.	46.	-34.	92.	58.	-112.	216.	104.	SIMPLE HF,MIN RED,SEP AS DEV-50%
15	-64.	167.	103.	-112	107.	42.	-176.	274.	98	ADS, SAT
16	-96.	150.	55.	-113	107.	41.	-209.	257.	49	ADS, SAT, SEP AS DEV-50%
17	-44.	167.	123.	-112	107.	56.	-156.	274.	118	ADS, SAT DL ONLY
18	-76.	150.	74.	-113	107.	55.	-189.	257.	69	ADS, SAT DL ONLY, SEP AS DEV-50%
19	-51.	222.	170.	-180	75.	16.	-231.	296.	66	CIS, MULTI SAT
20	-51.	288.	237.	-180	75.	16.	-231.	363.	131	CIS, MULTI SAT, FREE VERT FLIGHT
21	-51.	248.	197.	-180	75.	16.	-231.	323.	92	CIS, MULTI SAT, 60-30 C, MNPS